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## The East River Tunnels of the Pennsylvania Railroad.

The magnitude and unusual character of the tunnel work now being prosecuted by the Pennsylvania Railroad in connection with its new New York City terminals is attracting attention among engineers not only in this country but also in Europe. It is the greatest tunnel work ever undertaken. In addition to this, engineers familiar with the physical conditions in the East River have anticipated from the first that the responsible engineers of this great work had before them the solution of problems more difficult than any hitherto encountered in any tunnel enterprise so far successfully completed. It is equally true that these engineers have had a thorough appreciation of the difficult character of the work before them. This is well attested both by their own experience and by the extraordinarily comprehensive and thorough examinations made by them of the material to be penetrated under the East River as well as by the comprehensive plans and specifications set forth in the invitations for tenders prior to the awarding of the contracts.

It is not a matter of surprise under these conditions that the progress of the work should be from time to time checked by the existence of unusual difficulties manifested by the external disturbances along the tunnel line across the East River which have so agitated the public during the past few weeks. The almost volcanic eruption of the water over the tunnel workings by the escape of compressed air, the settling of ferry structures, and the deposition of many scow loads of clay or other filling, seemed to the public to augur perhaps insurmountable obstacles to the progress of the work. The daily press, always too ready to give sensational significance to any occurrences out of the ordinary, has set forth alarming statements as to the causes of these phenomena and have intimated that the plans of the work or possibly some portions of the work itself may have to be abandoned. It is even stated on what appears to be authoritative grounds, that corporate and financial interests inimical to the Pennsylvania Company have made use of these supposed extraordinary difficulties in the progress of its tunnel project at New York for the purpose of obstructing or possibly defeating plans for financing this or other portions of its current work.

In order that the actual engineering conditions of this great project, of so much importance not only to the city of New York, but also to many other large corporate interests centering in that city, might be authoritatively given The Engineering Record has made a thorough examination of the work through the courtesy of the Pennsylvania Company, and there will be found both in this and the succeeding issue of this journal a full account of the work as it now stands. It will be of the highest interest to engineers to know that while serious difficulties, largely anticipated, have been met they are being effectively overcome. In fact the present conditions of the work, in spite of all that has happened, are such as to give confident assurance that the tunnels will be completed essentially on time. While it is obviously not practicable to foresee all exigencies which may yet arise, there is no reason whatever to suppose that anything more serious than that which has happened can occur.

There are some features of the method of tunneling by shield in soft material, or where soft material changes to rock, which are encountered in the most aggravated form under the East River, precisely as was originally anticipated by the chief engineer. In the earlier and smaller tunnels where the pneumatic method has been used, the diameter or height of the heading was comparatively small, so that the difference in hydraulic pressure between the top and bottom of the tunnel was not of great moment. The circumstances in such great tubes as those of the Pennsylvania tunnels, about 23 ft. in diameter, however, are substantially different. The hydraulic pressure at the bottom is but little less than 1,500 lb. per square foot more than at the top of such a heading. As observed in the account printed in another column of this issue of The Engineering Record, if the material being excavated is soft and yielding, this condition will necessarily produce a large escape of air at the top of the heading without perhaps being sufficient to keep the water out at the bottom. Resulting blowouts of magnitude must necessarily be expected. It is imperatively necessary for the successful progress of such work to resort to various means to prevent undue disturbance of the conditions which at best are in unstable equilibrium. This is so serious a feature indeed that it is not unlikely to induce possible modifications of methods in future tunnel work under these difficult conditions. As a matter of fact, the freezing method is now undergoing a large-scale test in connection with this work, the results of which cannot fail to be of the highest interest to engineers. The impossibility of obtaining approximate parity of pressure between the compressed air and the water at the tunnel heading in such large tubes is so serious a working condition that it may lead to material changes of procedure by which this lack of essential equilibrium may be avoided in soft material. The construction of tunnels under the East and North Rivers is in all probability but just begun. Indeed the enormous daily passenger traffic between the Boroughs of Brooklyn and Manhattan would be facilitated in the highest possible degree by large tunnels, whose construction can scarcely be considered practicable with the shield method, but which would yield precisely the relief which is now being sought under such pressure if suitable methods of construction can be found.

The satisfactory engineering conditions attending the construction of this work, in spite of the difficulties which have arisen, is not less gratifying to engineers interested in tunnel work than the circumstances attending the use of compressed air at pressures as high as 32 to 35 lb. per square inch above the atmosphere. The statements found in another column of this journal show that those in responsible charge of the work have fully appreciated the necessity of providing thoroughly against the physiological effects of compressed air on the laborers engaged in the work. The utmost care is observed both in entering and passing out of the air locks. No means known at the present time to either the engineering or medical profession is omitted in caring for every member of the force engaged. In spite of the fact that sensational statements have been printed from time to time, the records show that the effects of compressed air have been reduced to an unusually small amount. Indeed, it can be authoritatively stated that not only is the progress of this work in its present condition satisfactory from an engineering point of view but also that no means are being spared to continue it to a successful issue in the care of the men engaged in it as well as in every other respect.

## General Specifications for Water Purification Works.

The most natural way to contract for public works with competitive bidding is under specifications which fully and adequately describe the work to be done and the materials to be furnished. To proceed successfully in this way the public authority must know exactly what is to be secured, must be prepared to take full responsibility for it after it is delivered in accordance with the specifications and must make sure that the materials ordered or the work to be done are well suited to their uses. These conditions require good judgment and oftentimes engineering skill.

Another method is to advertise for bids under general specifications. Bidders are told the general result that is desired and are asked to submit plans for reaching it, together with bids for carrying out the work under those plans. In this case the bidders are also usually and properly asked to take all responsibility for the plans as well as for the materials and workmanship. This feature of contracts under general specifications is extremely attractive to non-professional commissioners who dislike to take responsibility for matters of design, and who either do not know how to secure adequate professional assistance or are unable or unwilling to get it.

General specifications are very useful when rightly used, and they may afford the only way of reaching desirable results. Sometimes when a patent covers a desirable way of reaching a given end, but not the only one, such specifications afford the best means of securing actual competition, and in a business-like manner allowing the use of the patent, if the holder of it is the successful bidder, without even the appearance of favoritism. General specifications are also particularly useful in buying manufactured products, when the materials purchased under one contract are but a fraction of the regular output of a large shop. In such a case the various bidders can properly be allowed to take advantage of their own particular patterns, forms and patents, if they have them, which could not be specified without injustice to other manufacturers. It is essential that the end to be reached should be clearly and unmistakably defined, and that the attainment of it should be capable of being shown by simple and sure tests.

As the manufacture is standardized and the product becomes uniform, well-known and reliable, this procedure becomes more certain and satisfactory. At the same time the converse is equally true. Where work has not been standardized, where the requirements are variable, or where certain and sure tests of the product or results cannot be easily applied, the use of general specifications becomes less sure and less satisfactory and more likely to lead away from the intended goal.

In building works for the purification of public water supplies both general and definite specifications have been used. There are difficulties with general specifications for works of this character which do not exist in the case of water meters, or pumps, or even bridges. The methods and forms of construction are not, and to some extent cannot be, well standardized, except as to some models of limited application. The conditions to be met are hardly the same in any two cases, and even in a single case they may vary from day to day, so that an arrangement successful at one time may fail at another. Furthermore, the results to be produced are not capable of precise determination as is the case, for example, in testing a pumping engine. There are various substances to be removed from the water, and the degree of their removal is generally incapable of exact determination. Even if it were, other conditions than those controlled by the bidder so largely enter into the final result that these means do not afford an adequate basis of deciding as to the merit of a design. Notwithstanding these difficulties most of the water purification plants thus far installed in this country, although not the largest or the most important nor the best, have been installed under general specifications. It is to be noted also that a large part of the works so installed have fallen far short of what might reasonably have been accomplished by other means.

The greater and more certain profit to bidders under general specifications, and the persistent campaign to continue the practice by those interested have had much to do with maintaining this condition. Claims as to patents, not investigated by purchasers, which are often partly or wholly unfounded, have also played a part in the award of many contracts entirely without competition at liberal or more than liberal prices.

The man who understands something of water purification and knows what may reasonably be done with a given water and situation, will certainly develop his plans and write his specifications, as far as he is able, to secure the works that will best serve those conditions. He will likewise be sure to specify accurately what he wants and will be willing to take full responsibility for it. But to the man who does not understand the situation and does not know what he may reasonably expect to do with it, it is an extremely attractive proposition to make a contract under general specifications, which, as he thinks, puts all responsibility upon the bidder, and leaves him free of a load which he does not wish to assume. The contract is then awarded cheerfully without the thought that in the end it is to prove a gold brick, because each official, though he knows that his neighbors are sometimes taken in, thinks himself too sharp to be caught.

Practically all of the largest and best, and also some of the very worst water purification works in this country have been built under definite plans and specifications. Some very creditable and innumerable mediocre and bad ones have been built under general specifications. Although there is much to be proud of, and much to regret in the record, there is a tremendous chance to improve and to make the works of the future more substantial, more efficient and more economical than those of the past. Certainly the way to accomplish these results, if the future is to be judged by the past, is not through the use of general specifications.

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## Power Schemes for the Rand.

The great demands of the South African mines for power, the present unorganized means of meeting these demands in any way at all economical, and the growing tendency throughout the world toward the generation of electrical power on a huge scale for distribution over considerable areas, have united in bringing forward several extremely interesting power schemes for the Rand. As these projects appear to have behind them sufficient backing to insure the most thorough working out of the preliminary engineering problems, and with capital waiting to carry out that one which shall most satisfactorily establish its superiority, the time appears not far distant when South Africa will rank only second to the Niagara Falls district in interest to the power engineer.

Of the two leading schemes, that which deals with transmission of power from the Victoria Falls of the Zambesi River is by far the most striking. Of its ultimate magnitude one can hardly form an estimate, but even in its beginning it will, if carried out, rank as the most notable power project yet undertaken, for it involves distances of transmission entirely without the scope of present experience. It is more than 700 miles as the crow flies from Victoria Falls to the mines of the Rand, the nearest market for power. Between lies only forest and veldt, with the kraals of natives and the huts of British pioneers. It is a country doubtless one day to be great, for in the next century the one time Dark Continent is likely to be the scene of world struggles for pre-eminence; but at present the day of rapid industrial growth has not yet come. As a concrete project the transmission from Victoria Falls means sending 50,000 kw. or so over a straight away line to a region where there is fairly cheap coal already used for power transmission to the mines that obliterated two republics. The hydraulic development on the scale now undertaken is comparatively simple, and the difficulty lies in the transmission on an economical basis of a comparatively moderate amount of energy to an unprecedented distance. When the project was first considered, more than a decade since, the outlook was undeniably cheerless, but as time has gone on and experience at high voltage has been acquired, the difficulties have decreased until in its rejuvenated form the scheme begins to take on a practical aspect.

It reduces itself, in fact, to the problems of limiting voltage and of keeping in service a line 700 miles long through an African wilderness. The questions of generation and utilization may be left to take care of themselves, save in so far as they may vary somewhat with the kind of transmission undertaken. The pole line is somewhat formidable as pole lines go, since it would probably cost in duplicate something over a million dollars at the least, aside from all questions of conductors. But the cost of conductors is staggering at or near any voltage yet projected, much less tried. At a working pressure of even 100,000 volts and 10 per cent. loss, the copper required would be more than 35,000 tons, costing at present prices about $14,000,000 undelivered and unstrung. Weighing 50 tons to the mile, it would carry down any ordinary pole line, and to support it a great increase in the cost noted above would have to be allowed for. It would be remarkable indeed if the line could be built complete for less than $20,000,000 on a 100,000-volt basis. This means a capital charge of $400 per kilowatt for the line alone, worked at 100 per cent. load factor. With any reasonable estimate of other charges, it is obvious that the commercial success of the project must depend on the use of a voltage greatly in excess of 100,000. At 200,000 volts the scheme takes on a business-like aspect and somewhere between these figures lies the minimum economic voltage for the conditions. How near can twentieth century engineering come to meeting these formidable requirements?

To begin with, the highest voltage now in use is 60,000. Most of the dozen or so plants rated at this figure are actually working some thousands of volts below it, some as low as 45,000. Plants for 70,000 to 80,000 volts have been planned, but with transformer taps or connections contemplating 50,000 to 60,000 as a safety precaution. No insulators suitable for even 75,000 volts with a really adequate factor of safety have yet been produced. At 150,000 volts, about the lowest figure to be seriously considered for the great African project, the normal striking distance is 15 in., and with a factor of safety even so low as 2, the sparking clearance of the insulators, wet, would have to be some 30 in. The distance of the transmission comes dangerously near to a quarter wave length for the alternating frequencies now in general use, and it is clear that an alternating current of exceptionally low frequency must be used to avoid troubles on the line. So serious has the line problem appeared that the feasibility of transmission by direct current is being taken into grave consideration. Such a system is practically unknown in this country, but its success on the Continent has been certainly enough to warrant investigation. Unquestionably its use would lessen considerably the difficulties of insulation, since the sparking distance with alternating current is determined by the crest of the wave. For a given factor of safety, the sparking distance in the insulators could be reduced about one-third and the purely inductive troubles on the line would disappear, although a certain amount of surging and all the difficulties due to lightning would remain. Inasmuch, however, as the voltage on a constant current line reaches a maximum only at full load, the average strain on the insulators would be very greatly reduced. Another possibility perhaps worth investigation is a constant-current, alternating-current line, which would simplify the generation and distribution and lessen the average strain on the insulation. Look at it as one may, the Victoria Falls project is one that involves very formidable engineering difficulties which are far beyond the limits of present practice. On the other hand, it is not safe to call them insuperable, though the project may have to await further experience and a greater need for power before it is brought to completion.

In comparison with the Zambesi scheme, the other large South African project now under advisement is almost prosaic in character. This contemplates the generation of electric power by steam, its transmission about 50 miles to a central point, and distribution therefrom over a radius not exceeding 25 miles. The generating plant would be located in the vicinity of mines which provide coal of a fair quality, and water for condensation would be taken from a large storage reservoir, drawing its supply from the Vaal River—the reservoir being necessary on account of the low stage of water in the Vaal at certain seasons. The plan provides for seven steam generating sets, each of a capacity of 10,000 kw., and capable of sustaining an emergency overload of 25 per cent. With one set kept in reserve, the total normal capacity of the plant would thus be 60,000 kw., with an overload capacity of 72,000 kw., which is considered sufficient to meet the present requirements, not only of the Rand mines, but also of contemplated electric railways from Johannesburg to Bloemfontein and to Pretoria. The estimated capital outlay is $10,000,000, of which one-half would be absorbed by the generating plant. It is stated that all the money necessary for the preliminary expenses of this scheme has been supplied, and that certain financiers have expressed their willingness to supply the greater part of the capital for the undertaking as soon as it is required. This project, it will be seen, does not involve any untried engineering features, and the entire equipment would not vary greatly, if any at all, from present standard practice. Owing to these considerations, the cost of generating and delivering power can be very closely calculated, so that the scheme on its face is apt to appeal to financial interests with much greater force than the ambitious Zambesi project with its many uncertainties. Since, moreover, it is claimed that the capital outlay will be very much less than for the latter scheme, we fear that engineers will, in the present period at least, be denied the solution of the many great problems involved in transmitting power at an enormous voltage over a distance of 700 miles.

## The Growing Importance of Technical Education.

The rapid increase which has taken place, during recent years, in the number of men engaged in constructive and manufacturing operations which require more or less technical knowledge makes the subject of technical education one of very great importance, not only to the engineering profession, but to the public at large. In the year 1904 there were granted by the various technical schools in this country over 2,400 baccalaureate degrees in engineering courses, and during the past month the number of such degrees granted has doubtless exceeded 2,600. There are now annually enrolled in something like 125 technical schools over 20,000 students in engineering. In the highly developed country of Germany the number in the higher schools of technology is nearly as great, while an equally large number are enrolled in technical schools of secondary grade other than trade schools. This growth in technical education during the past decade has been one of the most striking occurrences in the educational field and has in many centers of learning completely upset the customary balance of numbers and seriously changed the relative importance of the various departments of instruction. The engineering school in most universities has far outstripped the older professional schools and a very large part of the energy of some of the largest institutions is now devoted to the teaching of engineering students.

In spite of this great growth in students and graduates, if reports from schools and from engineers can be credited, there never was a time when the college man could so readily gain a foothold in the profession as at present. Only a faint remnant now appears of the previous general distrust of the ability of the college man to do good work, a result, we believe, due quite as much to the better understanding by the employer of what a college training can and cannot do for a young man as it is to any improvement in the character of the instruction. We cannot agree with those who lament the large numbers of technical graduates now being turned out annually. The ready absorption in recent years of these large numbers is, in our judgment, due not only to the general prosperity of the country, but to the widening of the field in which the technical man is found to be useful; and if our technical schools rightly adapt their work to the changing conditions, we have little to fear from an oversupply of usefully trained men. The narrow profession of thirty years ago was much more easily overcrowded than that of to-day.

The importance of technical education is reflected in the frequent papers and discussions before engineering societies and in current periodical literature; and its recognition is of special value to those in charge of this work at the annual meetings of the Society for the Promotion of Engineering Education. This society has just held its fourteenth annual meeting at Ithaca, N. Y. The discussion at this meeting and at the convention of the American Society of Civil Engineers of the previous week have been of more than usual value and interest. At the Ithaca meeting the most noteworthy paper was probably that presented by Mr. John F. Hayford, of the U. S. Coast and Geodetic Survey, on "Why Not Teach About Men, the Most Difficult Tool an Engineer Uses?" A paper of somewhat similar trend was that by Mr. Basset Jones, Jr., consulting engineer, on "The Benefit of Philosophy to the Engineering Student." These two papers called forth a general discussion in which breadth of training and good teaching were emphasized in a most unanimous manner. Little time was devoted to details of curriculum, as these matters have received special attention at meetings of recent years.

A very large majority of those now entering the engineering profession are receiving a preliminary training in college, and the only question of practical importance is, not whether a college education is advantageous, but what such an education should be both in quality and quantity. Just how much, and what subjects, can be economically learned in a school is and always will be a question upon which there will be differences of opinion. As Prof. Swain well said in his discussion at the convention of the American Society of Civil Engineers, "Engineering is much more 'gumption and common sense' than it is science, and involves very many things that cannot be learned in schools." It is nevertheless true that with the progress of discovery in the physical sciences and the more exacting requirements and great complexity of modern practice, the time which can profitably be devoted to study in a school tends gradually to increase. The theory of to-day will enter into the practice of to-morrow, and likewise is it true that the empirical practice of to-day becomes reduced to law and principle to-morrow, and worthy of mastery as such. In the early days of engineering study in this country, one year, with a very simple preparation, was considered sufficient to cover the principles of practical science, while to-day a four-year course following an equal period of preparatory work is about the least considered as at all adequate, and is coming to be an absolute requirement in many cases. Of course development along this line will not be as rapid in the future, but that we have reached the end is not to be presumed.

How and in what way the development will proceed is of the greatest importance to this country, but it seems certain that it is only by such joint discussion between those who are primarily engineers and those who are primarily educators that the best ends will be attained.

## Notes and Comments.

Standardization of Weights for scientific work, manufacturing and commerce will be undertaken by the U. S. Bureau of Standards at Washington. This standardization will be limited for the present to masses up to 50 lb.

An Unusual Bridge Project is now under way for bridging the Mississippi River, at St. Louis. By a recent public vote the project of a free municipal bridge was approved by a large majority. Under this ordinance a sum of $3,500,000 becomes available for "the construction and maintenance of a municipal bridge for public use by railroads, street cars, vehicles of all kinds, and pedestrians over and across the Mississippi River, and for the purchase of land to be used for approaches thereto." It is not yet stated what length of span will be employed in this structure, nor what will be its capacity as to railroad tracks, roadways and sidewalks, but undoubtedly it will be an unusually heavy structure. The Mississippi River is already well bridged, so to speak, at St. Louis, but the project to construct additional facilities of this class has long been agitated. Apparently this new structure will be so located and designed as to give the freest possible accommodations for not only railroad traffic but other classes of business.

The Meat Packing Industry received such a set-back from recent official "investigations," so-called, that it is gratifying to learn the real facts from reliable people competent to examine intelligently the important details of the business. This commission consisted of Dr. W. A. Evans, professor of pathology at the University of Illinois; Dr. Maximilian Herzog, late pathologist of the Bureau of Science at Manila; Dr. M. P. Ravenel, pathologist to the Phipps Institute; Prof. A. T. Peters, V. S., University of Nebraska, and Prof. M. H. Reynolds, V. S., University of Minnesota. These men, far more reliable judges of the condition of the plants than the two presidential investigators, confessed without any knowledge of slaughtering and packing, report that the product is "wholesome," the yards "generally clean" and the inspection "efficient." Some of the older plants needed improvements, which are being made, but in most cases the desirable changes are in minor details. The investigation revealed just the same conditions that would be found by a similar examination of hospitals or schools; the new buildings would be satisfactory and the older ones unsatisfactory, and probably in some few cases wretched plumbing, ventilation or lighting, tending to affect seriously the health of considerable numbers of people, would be discovered. If anybody raised a hysterical fuss over these exceptional cases he would be considered irresponsible, and the same observation applies to the recent wholesale attack on the packing industry.

# THE CONSTRUCTION OF THE EAST RIVER DIVISION OF THE PENNSYLVANIA, NEW YORK AND LONG ISLAND RAILROAD COMPANY'S TUNNELS.—I.

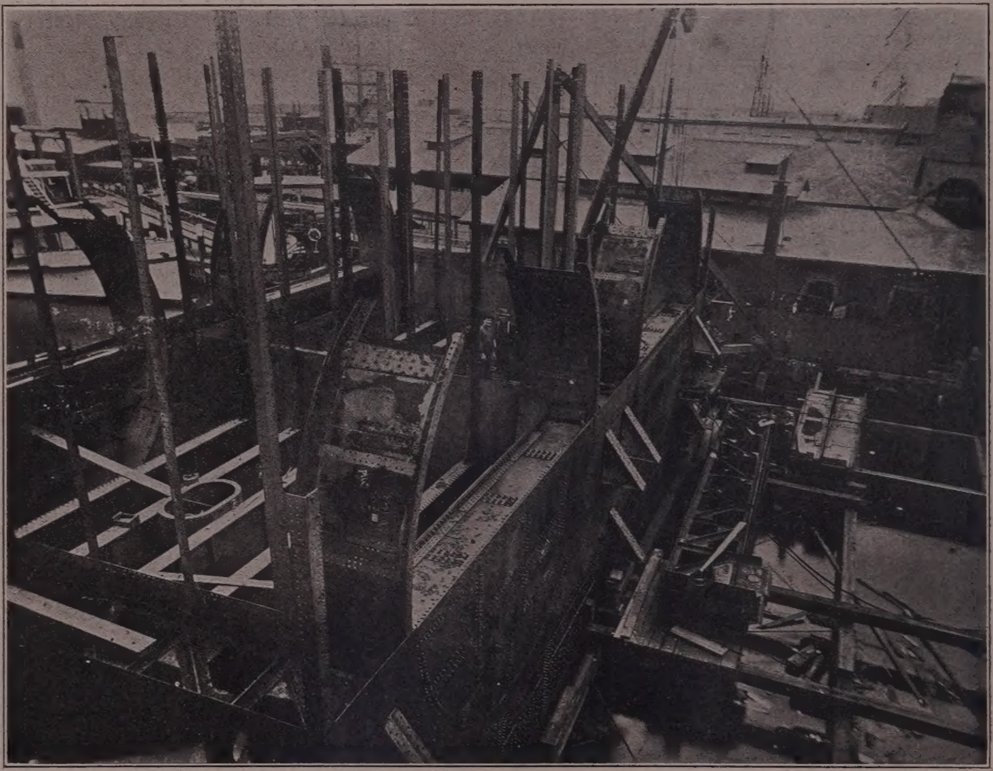
The Pennsylvania, New York & Long Island Railroad extends from the State line between New Jersey and New York in the North River eastward to a point near Woodside, L. I., a distance of about 31,000 ft. The Pennsylvania, New Jersey and New York Railroad extends from the State line in the North River westward to a junction with the present line of the Pennsylvania Railroad near Harrison, a distance of about 42,000 ft. The tunnel lines of the two companies collectively embrace a distance between the portals of about 29,500 ft. The Pennsylvania, New York and Long Island Railroad connects the tracks of the Long Island Railroad in the Borough of Queens, New York, with the great new underground terminal station of the Pennsylvania and Long Island Railroad Companies between Seventh and Ninth Aves and Thirty-second and Thirty-third Sts., Borough of Manhattan, New York City. It forms a part of the improvement costing many million dollars that is now well advanced for the connection of these existing railroad systems, for the development of suburban traffic, and for a connection with New England systems.

This great undertaking involves very important and difficult work, some of which is practically without precedent, and is being executed by the most advanced methods and the use of great quantities of special and improved mechanical apparatus operated almost exclusively by steam, pneumatic, hydraulic and electric power. The principal divisions of the work are the North River divisions including the land tunnels under Bergen Hill and on the western part of Manhattan Island and the tunnels under the North River, and the East River division which includes the terminal station, land tunnels on the east side of Manhattan Island, subaqueous tunnels under the East River at Thirty-second and Thirty-third Sts., and land tunnels and approach work at Long Island City.

The structures comprise in round numbers nearly 12,000 lin. ft. of single track, concrete lined land tunnels; nearly 9,000 ft. of two or three track concrete land tunnels; about 1,600 ft. of single track concrete tunnels built in cut and cover; nearly 3,800 ft. of four to seven track concrete tunnels built in open cut and in cut and cover; 1,700 ft. of three and four track reinforced-concrete tunnels, and about 24,000 ft. of single track cast-iron shell tubular subaqueous tunnels under the North and East Rivers.

Work on nearly all of these different types of construction has been in progress for some time, but owing to the magnitude of the work, the very difficult conditions involved and the uncertainty of developments which might require departure from the original plans it has not heretofore been deemed wise by the management to publish any information concerning the progress and magnitude of work. The principal features of the contract drawings and specifications for the land and river tunnels were fully illustrated and described in The Engineering Record of Oct. 10 and 17, 1903; since then accounts of the Weehawken shaft and of the manufacture of the shields have been published in The Engineering Record and little or no other authorized information has appeared in technical journals concerning the progress of the work until the account published in The Engineering Record of July 7, which gave a general description of the progress and conditions of the East River division of the work.

Many of the difficult problems involved in the execution of the work have now been satisfactorily met, the principal items of the contractors' plant have been installed and a large portion of the work has been successfully completed. It is therefore considered that the present conditions warrant the publication of the principal features of the work between the East River shafts, and in accordance with this decision the general advance description of the conditions, published in The Engineering Record last week will be supplemented by the present article and others describing in detail some of the interesting features of construction from data authorized by the engineers and contractors. Part of this information was secured from official drawings and photographs, but a large proportion of it is prepared from special notes and investigations which were made by the staff of the Engineering Record.



Building Tunnel Drums in Caisson.

That portion of the East River division of the Pennsylvania, New York and Long Island Railroad between First Ave., New York, and Thompson Ave., Long Island City, has a total length of about 9,600 ft. and includes about 3,000 ft. of subaqueous tunnel under the East River and about 3,800 ft. of land tunnel in the Borough of Queens, the remaining distance being occupied by approaches. The East River tunnels consist of four parallel single-track cast-iron tubes 23 ft. in external diameter. These tubes are 37 ft. apart in each of two pairs, which converge from 225 ft. apart on centers, at First Ave., New York, to 103 ft. apart at the Front St. shaft, Long Island City. Each pair connects the bottoms of shafts, four in all, from 74 to 88 ft. deep in the Boroughs of Manhattan and Queens.

From the Manhattan shafts four single-track land tunnels extend westward to the terminal station and from the Queens shaft four land tunnels extend eastward to the portal where they connect with single-track concrete tunnels. All of the work here described is built under the direction of Mr. Alfred Noble, chief engineer, and Mr. C. L. Harrison, principal assistant engineer, by S. Pearson and Sons, Inc., contractors; Mr. E. W. Moir, vice-president, and Mr. Henry Japp, managing director.

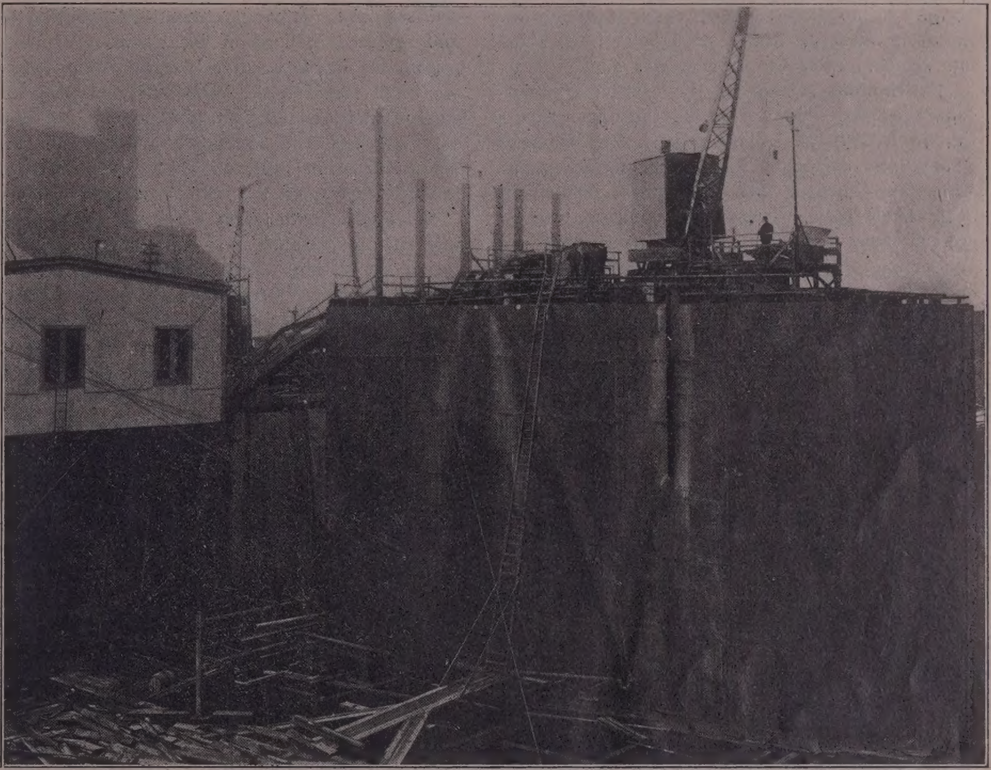
*Shafts.*—The river shafts were all sunk with rectangular steel and concrete linings about 40 ft. wide and 74 ft. long, which extend from the surface of the ground to the rock, and in Long Island City are carried down far into the rock and below the inverts of the tunnels. When the contracts were awarded it was uncertain whether or not it would be necessary in all cases to extend these linings to the bottom of the shafts. They were therefore designed to be used if necessary as pneumatic caissons and so that they could be stopped at the surface of the rock with their cutting edges above the tunnel tubes or so that upper sections like cofferdams could be added to them and they could be continued to the full depth if necessary. Execution of the work developed a remarkable conformation to the preliminary profiles and resulted in the use of the full-depth linings as expected in Long Island City, where the rock was poor and large quantities of water were encountered necessitating the excavation under pneumatic pressure, while in the Borough of Manhattan the rock was better and the caissons, sunk with open excavation were only carried down about half as far as on the opposite side of the river, the remainder of the shaft being made with ordinary excavation and having its walls faced with concrete lining. These conditions fixed the heights of the caissons at 40 ft. and 50 ft. for the south and north caissons respectively in New York, and at 84 ft. for both caissons in Long Island City.

The caissons for the Long Island City shafts are made as illustrated in The Engineering Record of Oct. 17, 1903, and except for a slight difference in their depths, they are duplicates, the north one intersecting single-track tunnels A and B, and the south one intersecting single-track tunnels C and D. Each of them has double vertical exterior walls 5 ft. apart made with flat steel plates ⅜ to ½ in. thick in horizontal courses 5 to 8 ft. high, spliced with butt joints and single cover plates. The walls are connected and stiffened by horizontal lattice girders from about 3½ to 5 ft. apart vertically with the vertical legs of their flange angles riveted to the inner and outer wall plates. The centers of the long sides of the caissons are connected by a transverse partition made like the outer walls, except that it is 6 ft. thick and will not eventually extend below the tops of the tunnels, although it has been temporarily carried down to 7 ft. above the cutting edge. The spaces between the inner and outer plates of the walls and partitions form pockets which are filled solid with concrete.

The bottom of the outer walls terminate in a cutting edge which virtually consists of two plate girders at right angles to each other. One of them has a vertical web 7 ft. deep in the outer plane of the caisson wall; the other has a horizontal web 5 ft. deep and corresponds with the girders connecting the inner and outer faces of the walls. These two girders are riveted together through the outer flanges of the horizontal one and are knee-braced at intervals of from about 3½ ft. to 5 ft. by transverse vertical diaphragms, with flange angles riveted to the web stiffeners of the main girders. The web of the vertical girder is reinforced by heavy continuous plates on the lower edge to make the actual cutting edge.

Two circular drums large enough to clear the tunnel lining are built in each long side of the caisson with their centers 37 ft. apart to correspond with the tunnel centers and about 23 ft. above the cutting edge. These were temporarily closed by movable bulkheads each made with six horizontal plate girders stiffening inside and outside wall plates ½ in. thick. These plates were spliced to the main wall plates of the caisson so as to give the latter a continuous surface calked water tight. Seven feet above the cutting edge the caisson was provided with an air-tight temporary steel floor not shown in the illustrations above referred to. The original design contemplated the use of a timber floor, but on account of the danger from fire and for other considerations the contractors decided to provide instead a steel floor. This floor was made with ½-in. plates, 6 ft. long and 5 ft. wide and curved to a radius of about 4 ft., forming cylindrical segments placed convex side upwards and riveted to the flanges of horizontal lattice girders about 7 ft. deep. This floor served as the roof of the working chamber and the caisson was sunk under pneumatic pressure. The caissons for the New York shafts were similar to those in Long Island City, except that the floor was omitted and that the height of the walls was reduced to about 36 ft. The four caissons contained together about 4,200 tons of steel and were fabricated by the Cambria Steel Co., Johnstown, Pa., and erected by the Jobson-Hooker Co., New York.

The North River shaft, Long Island City, is located in the Nassau Slip, in water about 16 ft. deep, and its caisson was assembled on a falsework containing 96 piles driven about 14 ft. through the mud to rock. At each corner of the caisson two rows of four piles each were driven parallel to and just beyond the outer walls of each face of the caisson and capped with 12 x 12-in. timbers. At the middle of each long side there were two rows of eight piles, each driven parallel to and just beyond the outer walls of the caisson and similarly capped. From each pair of caps there were suspended 15-in. cantilever I-Beams, 14 ft. long, projecting beyond the inner wall of the caisson perpendicular to it. Twelve of these I-beams were provided at each corner of the caisson and twelve at the middle of each long side, making seventy-two in all. These groups of I-beams at about low water level supported the cutting edge girders of the caisson which were received in single lengths for the ends of the caisson and in two lengths for each of the long sides. Their maximum shipping weights were 20 tons each, and they were received on lighters which unloaded them on the adjacent dock, where they were handled by a pair of stiff-leg derricks located on the center line of the caisson just beyond each end. These derricks had 70-ft. booms with nine-part hoisting and topping tackles rove with ⅝-in. steel rope and operated by hoisting engines built by the National Engine Works, Harrison, N. J.



**Elevated Office, Long Island City and Upper Part of Caisson with Traveling Crane on Top.**

**Lower Part of Caisson with Temporary External Brackets.**

The cutting edge girders were assembled on the cantilevers by these derricks, which afterwards built the walls of the caisson on them. The inner wall plates were first assembled, then the horizontal wall girders supported at the outer ends of the vertical stiffeners acting as temporary columns, and finally the outer wall plates. As soon as the walls reached the level of the bottom of the transverse wall, the latter was assembled in advance of the side walls, so as not to obstruct the operation of the booms. The walls in the long side were next erected, and those at the ends of the caisson were erected last, thus always maintaining clear space for the operation of the booms. The caisson was built to a height of 40 ft., and contained about 760 tons of steel when lowered to the bottom, after which it was continued to the full height of about 84 ft., and when finished contained about 970 tons of steel.

**Assembling Cutting Edge of Caisson.**

**Interior of Working Chamber of Caisson.**

The other three caissons had their cutting edges supported on timber cribbing on dry land, and were erected in a similar manner, except that those on the New York side were completed in one operation to the final height of 40 ft. The steel plate floor was assembled at a height of about 3 ft. above high tide, and was securely fastened with turned bolts to facilitate its removal after the caisson was sunk.

The bottom section of the caisson contained about 200,000 field rivets, and the upper section about 100,000, all of them ¾ in. in diameter. They were driven by fifteen pneumatic hammers of the Chicago, Ingersol, Pennsylvania and Cleveland types, operated by compressed air received from the tunnel plant. The riveting was under exceptionally favorable conditions, and was done by four-man gangs, one of which made the remarkable record of driving 1,500 rivets in nine working hours, a speed believed by the contractor to be greater than ever attained in any other field riveting. Part of the success was attributed to the use of compressed air blast and oil heating furnaces manufactured by the Rockwell Engineering Co., New York. The inside wall of the caisson was calked by pneumatic tools to a point above the second position of the steel floor. The entire outer surface and the steel floor were also calked with pneumatic tools. The upper section of one of the Long Island City caissons was unloaded from lighters, erected, riveted and calked complete in 24 days by a force of about 60 bridge men under the direction of Mr. John Jobson, of the contracting firm, and Mr. Samuel White, superintendent.

The north caisson at Long Island City was provided with 16 temporary triangular steel brackets about 4 ft. high and 3 ft. wide, with vertical web plates and horizontal and inclined flange angles, which were field-riveted to the outer walls at a height of about 20 ft. above the cutting edge. Under each of these brackets two piles were driven to the rock clear of the caisson walls, and were capped with 12 x 12-in. horizontal timbers parallel to the walls, on which were seated 100-ton hydraulic jacks engaging the lower horizontal faces of the brackets with wooden columns. It is interesting to note that the jacks included 10 that had been previously used by the tunnel contractors for the operation of the famous Blackwall tunnel shield.

After the completion of the lower section of the caisson, the jacks were operated sufficiently to release the 72 cantilever I-beams supporting the cutting edge, and they were removed, leaving the caisson suspended by its exterior brackets. The jacks were then uniformly slacked off enough to lower the caisson 8 in. Half of the jacks were then locked at this position and, together with temporary struts, supported the caisson while the other half of the jacks were released and removed, extended to full stroke and replaced in position with shorter struts engaging the brackets. The weight of the caisson was then transferred to the extended jacks, the caisson was lowered 8 in., the other set of jacks was removed and extended, and the alternate operations were repeated until the caisson was lowered to rest on the bottom of the river.

Air pressure was then admitted to the working chamber, water was expelled, and the interior excavation was commenced. Eight temporary triangular brackets were fastened to the cutting edge knee-braces, cribbing wedged up underneath them to support the caisson, and the outside jacks and brackets were removed. After the excavation was carried below the cutting edge, leaving the caisson supported on the inner brackets, the latter were jacked up to release the blocking, and two or three feet of the upper portion of it was removed, leaving the caisson supported entirely by the exterior skin friction and the interior air pressure.

The pressure was then reduced 5 to 8 lb., and in ten or fifteen minutes the caisson descended to bearing on the lowered surface of the cribbing. After the lower parts of the hollow walls were filled with concrete the caisson was additionally supported by blocking built up against the foot of the wall between the knee-braces, and the sinking of the caissons was accomplished as above described in successive operations which maintained constant control of it and limited the time and amount of its descent. The approximate weight of the caisson and concrete filling was 6,225 tons, which sufficed to sink it without additional ballast. The caisson was lowered 12½ ft. from the original position to the bed of the river in three 10-hour shifts.

The south caisson, Long Island City, was lowered substantially the same as the north caisson, except that the jacks reacted against crib work and no piles were driven for it. It encountered rock at a depth of about 23 ft., and, like the other caisson, was sunk until the upper edge of the walls was nearly down to water level, when the excavation was discontinued and the caisson walls were built up 42 ft. higher and the excavation and sinking resumed until the cutting edge was 78 ft. below mean high-water level.

The rock in the bottom of the working chamber was dressed to a curved surface corresponding with the intersection of two cylinders and was covered with concrete plastered with about 1 in. of cement mortar, waterproofed with six ply of felt and hot tar, protected with a second 1-in. coat of mortar and covered with concrete having a minimum thickness of 4 ft. and curved to top and bottom radii of 20½ ft. and 52½ ft. This made the invert of the shaft 14 ft. below the base of rail in the tunnel and formed a permanent sump for the drainage system.

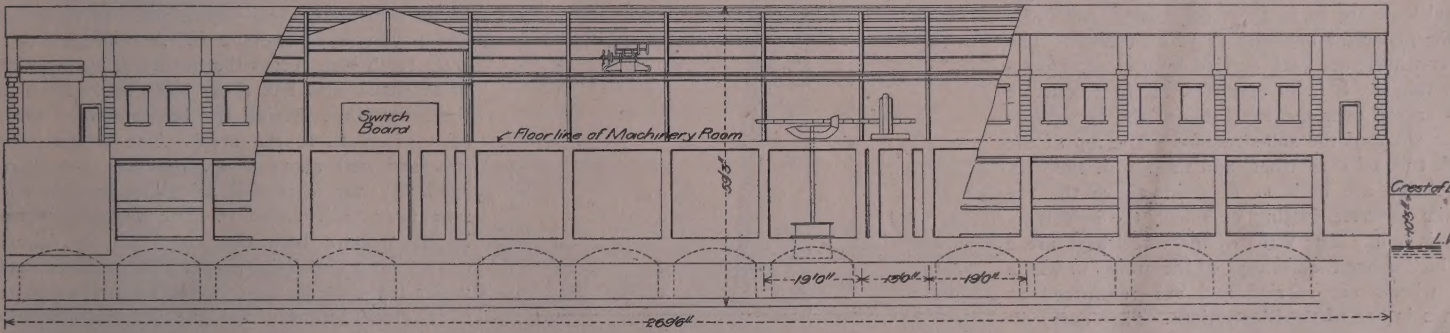
The concrete nearly filled the working chamber, and after its completion the air pressure was removed and the steel floor was taken out. The shields were then built on cradles in the bottom of the shaft, the steel floor replaced above them, air pressure restored, the circular bulkheads in the caisson walls removed and the shields driven out through the openings to commence the tunnel excavation. The concrete was made with Giant cement. It was mixed in a Ransome mixer on shore, about 150 ft. from the shaft, and was delivered in one-yard skips carried on surface tracks and lowered by the erecting derricks.

On the New York side the ground was good, and in order to expedite the construction a 20 x 40-ft. concrete pilot shaft was first sunk to subgrade by ordinary sheeting methods for each main shaft. These encountered rock at a depth of about 20 ft., and were sunk with a moderate amount of pumping. The steel caissons were erected over them in substantially the same manner as was the south caisson in Long Island City, but were not provided with any outside temporary brackets. There were, however, 16 interior temporary brackets on the cutting edge knee-braces, and these were used for supporting the caisson while the excavation was made as previously described. The cutting edge was lowered about 36 ft. below the surface of the ground to a stratum of satisfactory rock, where a berm was left to support it, and below which the excavation was continued by the usual processes of drilling and blasting. The spoil was hoisted from each shaft by a five-ton locomotive crane traveling on the transverse center wall of the caisson and handling ½-yd. buckets, which were emptied into 4-yd. rocker dump cars on the surface of the ground.

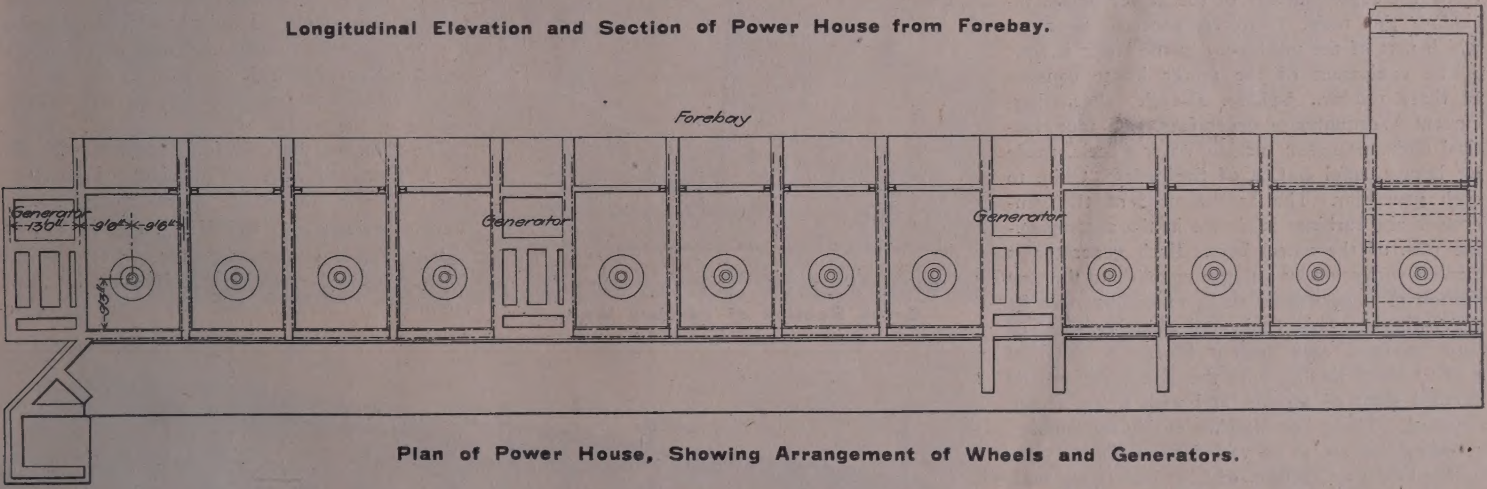
(To be continued.)

## A Hydro-Electric Generating Station at South Bend, Ind.

The machinery equipment of the manufacturing plant of the Oliver Chilled Plow Works, at South Bend, Ind., is practically all driven by electric motors supplied with electric power from a hydro-electric generating station on the St. Joseph River about 1½ miles from the plant. The St. Joseph River has a watershed of 3,000 square miles above this station that is largely made up of sandy soil from which the percentage of surface run-off is small. The river also heads in a number of small lakes and swamps, so that the stream flow is quite uniform. The low-water flow of the river is between 1,000 and 2,000 second-feet, and the maximum flood flow in the neighborhood of 15,000 second-feet. The normal low-water flow is in the neighborhood of 1,500 second-feet, while the higher stages of the stream frequently endure for some time. A number of hydro-electric stations have been built both up and downstream from the station at South Bend. Several other hydro-electric stations are also contemplated at various places along the river so that a large portion of the fall of the stream within 75 miles of its mouth will soon be utilized.



Longitudinal Elevation and Section of Power House from Forebay.



Plan of Power House, Showing Arrangement of Wheels and Generators.

The generating station at South Bend is on the left bank of the river and replaces a number of independent power developments that were formerly used to drive small manufacturing plants along the headrace supplying these developments with water. A rock-filled timber-crib dam, with a spillway 275 ft. long, is built across the river 520 ft. upstream from the power house of the generating station. A headrace also extends along the right-hand bank of the river for some distance downstream from the dam and supplies water to a number of small hydraulic developments on that side of the stream. The dam develops a head of about 11 ft. under average conditions. It is maintained jointly by the plants using water from both headraces, and the low-water flow of the river is proportioned equally between the latter. A municipal water-works pumping station containing three new American water-wheels driving power pumps uses water from the left-hand race for power. Otherwise the water from the headrace on that bank is utilized entirely by the generating station of the Oliver Chilled Plow Works.

The old headrace on the left-hand bank had a total length of a little more than 1,000 ft., and was from 60 to 75 ft. wide. Below the dam and between this race and the river was a strip of land 150 to 180 ft. wide. The various small plants which the new station replaces were along both sides of this headrace, flumes which extended through the strip of land between the river and the headrace carrying the discharge from their water-wheels. The power house of the new station is 28 x 270 ft. in plan. It is placed nearly parallel with the stream, with its upstream end 520 ft. below the dam, and is along what was the river side of the strip of land between the river and race. The end of the old race below the power house was filled in and a forebay excavated between the race and the power house the full width of the latter. The headrace was then widened until it had a uniform width of about 110 ft. from the forebay to the dam. Reinforced-concrete retaining walls were built along the sides of the headrace and forebay and the excavation in both of the latter carried to a practically uniform depth of 12 ft. below the crest of the dam.

The retaining walls along the headrace and forebay are all 18 to 19 ft. high. The typical cross-section of these walls is shown in one of the accompanying illustrations. The front face of the walls is vertical to a depth of 15 ft., and below that is on a 1 to 1 slope to the top of the footing. The back face is battered 1¼ in. to the foot. The wall is built on footing 8.25 ft. wide, the variation in height at different points being taken up in the portion of the wall between the 15-ft. depth and the bottom of the wall. The wall is reinforced near the back face by vertical rods extending into the footing; the latter is reinforced near the top by horizontal rods placed as shown. The reinforcement rods consist of scrap iron from the factory of the plow company, which rods were placed so an average of 1 sq. in. of steel section was obtained per linear foot of wall, but practically none of the material utilized exceeded 2.25 sq. in. in cross-section. The concrete in the wall consisted of one barrel of Sandusky Portland cement to 1 cu. yd. of fairly good bank gravel.

Four Parker-Taintor hydraulic gates, with a width of 20.5 ft. each, are placed in concrete settings built across the headrace, 150 ft. below the dam, to control the flow through the headrace. Two of these gates, each 20 ft. wide, are also built in the retaining wall on the river side of the race and between the four gates and the dam, in order to relieve the other four gates during high water. The arrangement of the four gates across the headrace is shown in one of the accompanying illustrations. The face of each gate is built of steel plates placed on the arc of a circle having a 20-ft. radius, with the convex side of the face upstream. This steel plate face is carried by a frame made up of structural-steel pieces. The main members of this frame are on radial lines of the arc on which the face is built. They are attached to hubs made up of steel plates which are attached to a horizontal 6-in. steel shaft set in sockets in the concrete. The gates seat at each side on the concrete piers which carry them and at the bottom on sills between these piers. The 6-in. shafts to which they are attached revolve in the sockets. The gates are each raised, lowered, and held in position vertically by two cables, one fastened on each side near the bottom of the face. The cables are attached to drum wheels on a shaft mounted on the piers. The shafts are geared to operating wheels so the gates may be raised and lowered by hand.

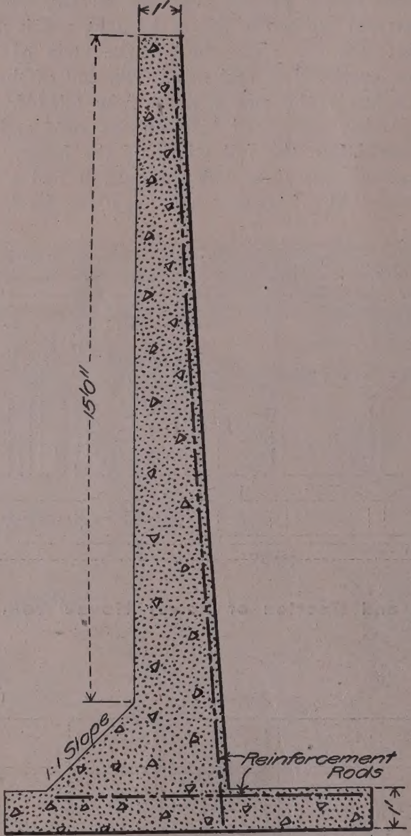
The power house has a reinforced-concrete sub-structure, with a steel-frame super-structure, having concrete block side walls independent of the steel frame. It has a roof of hollow tile carried by T-irons on steel-truss frames and covered with roofing felt and gravel laid in tar. The sub-structure is built on a flat concrete slab, 50 ft. wide, and 275 ft. long, which is laid directly on the gravelly bottom of the excavation and is about 2 ft. thick. The power house contains

Parker-Taintor Gates in Headrace.

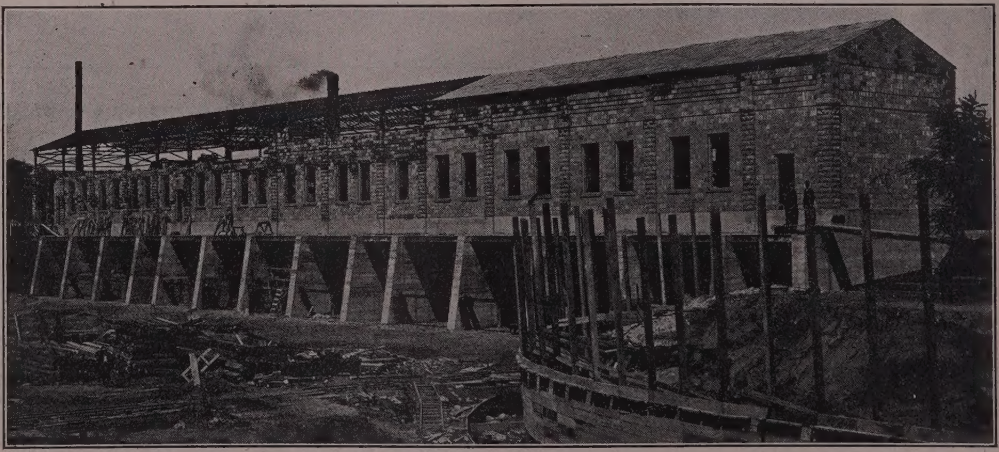
three generators and twelve water-wheels, all placed in a single row the length of the building. The sub-structure consists of transverse walls of concrete, which carry the settings for the water-wheels and generators. Four wheels are provided for each of the three generators and a separate bay is provided for each wheel and each generator.

The transverse walls forming the sides of the wheel bays are 19 ft. apart on centers, and those of the generator bays are 13 ft. on centers. The water-wheels are each carried by a circular cast-iron thimble, 8 ft. in diameter, set in a concrete slab arched over the bay between the two transverse walls of the sub-structure. The top of the draft tube of each wheel and the top of the concrete slab are both 11 ft. 9 in. above the top of the concrete footing on which the sub-structure is built. The walls of the wheel bays are 2 ft. thick above the flat tops of the arches in which the wheels are carried and are reinforced as shown in one of the illustrations. They carry directly the superstructure of the power house, including the 12-in. reinforced-concrete floor on which part of the machinery in the latter is set.

The equipment of the power house consists of three 500-kw., 3-phase, 25-cycle, alternating-current Westinghouse generators, and four vertical 68-in. Sampson turbine water-wheels, made by James Leffel & Co., of Springfield, Ohio, to each generator. The arrangement of the generators and turbines is shown in the accompanying plan of the wheel bays. Each generator is directly connected by a flange coupling to the first section of a horizontal shaft, extending over its four wheels. This horizontal shaft consists of four sections, each section having a cast-iron pinion, which meshes with the core wheel on the vertical shaft of turbine, and with a jaw clutch coupling. These jaw clutches enable the number of wheels in use to be varied from one to four, as the load may require, without interfering with the operation of the generator. The turbines operate at 77 r.p.m., and the generators at 214 r.p.m., this speed being maintained by a Lombard governor. A 20-kw., direct-current Westinghouse generator is provided as an exciter for each large generator and is belt-driven from the shaft of the latter.



Cross Section of Forebay Wall.



Power House from Forebay During Construction

The switchboard and series transformers for the instruments are in a 9-ft. 8-in. x 26-ft. room on the rear side of the building and toward the downstream end. This room opens into the main machinery room and is on concrete walls which are a part of the main super-structure. The switchboard is of standard Westinghouse construction and has eight panels. One panel is provided for the exciters, one for each of the generators. There are three feeder wire panels, one for lines leading to a large hotel, which is supplied with current for lighting and power, and one for each of two lines of feeder wires leading to the manufacturing plant. Current is generated and transmitted to the hotel and the factory at 6,600 volts, where it is stepped down to 440 volts. The wires in the station are all in bituminous-concrete conduits laid in the concrete floor of the machinery room. The transmission lines leading from the station are in McRoy vitrified-clay conduits laid underground.

A 10-ton traveling crane, built by the Whiting Foundry Equipment Co., travels the length of the machinery room on runways on the steel frame of the super-structure. A hatchway, 8.25 x 8.6 ft. in the clear, is provided over each wheel bay. This hatchway is covered by a reinforced-concrete slab, 8 ft. 10 in. square. These slabs are each provided with a ring in the top at the center and are lifted off the hatchway by the crane, so that each of the wheel bays may be entered without difficulty from the floor of the machinery room. The crane is also used in handling machinery.

A cofferdam was built across the upper end of the headrace and one along the river side of the power house, so the latter, the forebay and the headrace walls could all be built in the dry. Practically no difficulty was experienced in the construction work. When the headrace had been completed, water was admitted to it through the upstream cofferdam. Two days after the water had been turned in, a wash started under the wall on the river side. The cofferdam could not be rebuilt until the wall on the river side had been undermined for some distance near the middle of the race. The wall had a clear span of 80 ft. at the point where it was undermined, but the only indication of any damage to it was a slight vertical crack that developed at the center of this span. The wall is on a curve which had a versine of about 2 ft. A reinforced-concrete footbridge across the headrace, having nine 11-ft. spans, also had three piers washed out at the same time, leaving the bridge with a clear span of 48 ft. at the break. The bridge floor was deflected about 1 ft., but was not damaged. It was afterward raised to position and new piers built under it. The accident is believed to have been due either to the failure of a tile sewer built across the headrace and under the wall near the break, or to the failure of a flume leading from the water-works station to the river, parallel to the sewer. The cofferdam was rebuilt as quickly as possible, then the place washed under the wall was filled in again and covered with concrete, so that no further trouble has been experienced from undermining of the walls.

The plant was built by force account, with Mr. B. J. Campbell as superintendent of construction, under the immediate direction of Mr. L. Le Van, superintendent, and Mr. J. F. Wagner, assistant superintendent for the Oliver Chilled Plow Works. Mr. Thomas T. Johnson, hydraulic engineer, of Chicago, acted in a consulting capacity to that company during the design and construction of the plant.

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THE GENERATION OF ELECTRICITY in Prussia on April 1, 1905, required the use of 5,679 steam engines of 788,981 total horse-power. This was 5.38 per cent. of all the engines in the kingdom and 15.78 per cent. of their total capacity.

## The Award of a Contract for Public Work to a High Bidder.

Two months ago Judge McLaughlin, of the New York Supreme Court, Appellate Division, rendered a decision permitting the city of New York to proceed with the construction of the Cross River dam in the Croton catchment basin. Although this decision was reviewed editorially at the time, its importance is so marked that certain portions of it are reprinted here in full. The Judge first summarized the case, known officially as Walter v. McClellan, mayor, et al., 90 N. Y., Sup. 78, as follows:

*The Facts.*—"On June 21, 1905, the city of New York, acting by and through the Aqueduct Commissioners under the power vested in them by chapter 490, p. 666, of the Laws of 1883, and the amendments thereto, entered into a contract with the respondents MacArthur Bros. Co. and Winston & Co., by which the latter agreed to build a reservoir and dam at Cross River, in the county of Westchester, according to certain plans and specifications annexed to and made a part of the contract, for the consideration expressed therein. Prior to the making of the contract the Aqueduct Commissioners duly advertised for 15 consecutive days, commencing May 10, 1905, for sealed bids for the work. The notice published, notifying bidders, was quite minute in regard to the various details connected with the proposed work, the time when the same must be commenced and finished, together with a statement based upon the estimate of the engineer of the Aqueduct Commissioners of the approximate quantities of work to be done and materials to be furnished, which statement was divided into 49 different items. The bidders were notified that the quantities were approximate only, being given as a basis for the uniform comparison of bids, and that the Commissioners did not, expressly or by implication, agree that the actual amount of the work would correspond therewith, but reserved the right to increase or diminish the quantities of any classes or portion of the work as might be deemed necessary by the engineer. The bidders were required to satisfy themselves by personal examination of the location of the proposed work, and by such other means as they might prefer as to the accuracy of the estimates, and that they could not at any time after the submission of an estimate dispute or complain of such statement or estimate of the engineer, nor assert there was any misunderstanding in regard to the nature or amount of the work to be done. Special attention was called to the uncertainty as to the total quantity of rock to be excavated to prepare a foundation for the dam, since that would depend upon the character of the rock and the number of seams and other defects which could not be determined in advance. Also that the quantity of masonry to be built was liable to vary from the estimates for the same reason.

Temporarily Unsupported Spans of Bridge in Forebay, South Bend Power Station.

"In pursuance of the advertisement, seven bids were received, which, on May 31, 1905, were opened, and the chief engineer of the Aqueduct Commissioners was directed to tabulate the same, the result of which showed a difference of $263,711 between the highest and lowest bid; the highest being $1,344,030, and the lowest $1,080,319. The chief engineer's estimate of the cost of the work was $1,315,000. The bid of the respondents MacArthur Bros. Co. and Winston & Co. was $1,246,211.60, which was $165,892.60 more than the lowest. The chief engineer of the Aqueduct Commissioners was thereupon directed to make a report as to the financial standing of the bidders, including plants and ability to do the work, and each bidder was required to furnish the engineer with the requisite information bearing on such subjects. This direction, however, was subsequently modified by omitting the requirement as to financial ability and such inquiries were made by the comptroller. Different reports were thereafter made by the chief and consulting engineers of the Aqueduct Commissioners, the comptroller, and assistant engineers of the Department of Finance, which were finally considered and passed upon on the 20th of June, when a resolution was passed by the Aqueduct Commissioners to the effect that the bid of the respondents MacArthur Bros. Co. and Winston & Co. was the one, the acceptance of which would, in the judgment of the commissioners, 'best secure the efficient performance of the work,' and on the following day the contract was let to them, and they immediately thereafter entered upon the work."

This award was attacked by the plaintiff on five grounds, of which but three need be repeated here, viz.: (a), Because the character, location, extent and quantity of materials and work which may be required by the contract were not specified, limited or stated in the contract, nor was the liability of the city determined by the contract, specifications and plans; (b), because there was no such standard of comparison set forth in the notice to contractors and the advertisement as the law and competitive bidding require; (c), because the award of the contract at $165,892.60 above the lowest bidder was forbidden by Art. 3, Sec. 28 of the State Constitution. Counts (b) and (c) were considered together and count (c) was then taken up.

*Unit Bids.*—"The only question remaining to be considered is whether the contract asking for bids at unit prices for doing the work and furnishing the materials, and which might be increased or diminished as the work progressed, based upon an estimate of quantities, was one which the Aqueduct Commissioners had the power to make. There was no way, according to the uncontradicted testimony of the engineers, by which it could be accurately determined, when the contract was let, the exact amount of work or materials which would be required. The contract had to be let in one of two ways—either for a lump sum, which would require the contractor to do all the work for a given amount, or else for a specified price based upon estimated quantities by which the contractor agreed to do all the work for separate prices bid by him per unit of measurement, and it is difficult to see why one method is any more advantageous to the city than the other. Indeed, both methods have been adopted, and the legality of either has not, so far as I have been able to discover, heretofore been challenged. The former was approved in Lentilhon v. City of New York, 92 N. Y. Supp. 897, and the latter in O'Brien v. Mayor, 35 N. E. 323.

"In the O'Brien case the contract provided for payment by items and units of measurement, and contained substantially, in those respects, the same provision, and was entered into by the Aqueduct Commissioners under the same statute, as the contract here under consideration. Commenting upon this feature of the contract, Judge Peckham, who delivered the opinion, said: 'A perusal of the contract itself, as shown by the analysis already herein set forth, shows that it was drawn to provide for all the work of every kind and description which should be called for in the course of the building of this aqueduct, and for all such work and for the furnishing of all the necessary materials the contract provided special prices should be paid. Extra work or work outside of the character or amount of that specified in the contract was provided for and a way pointed out which was to be followed in order to bind the defendant.'

"In the contract now under consideration the obligation on the part of the city, including the method of payment to the contractor, is just as definite and fixed as it was in the contract in the O'Brien case. There is no material difference in this respect between the two contracts. Bidders here were informed, as already indicated, that the engineer, after having examined the site of the dam by means of borings, test pits, etc., had made an estimate of the nature and extent as nearly as practicable of the work required, and that the several bids would be tested by the quantities and kinds of work mentioned in the estimate. The estimate divides the work into 49 different items, consisting of excavations of different classes, refilling, timber, cement, concrete blocks, masonry of different classes, steel and cast-iron pipes, valves, culverts, and other work. Bidders were told that the quantities were approximate only, the same being given as a basis for uniform comparison of bids, and that the commissioners did not, expressly or by implication, agree that the actual amount of work to be done or materials to be furnished would correspond with the estimates, but that they reserved the right to increase or diminish the quantity of any class, if deemed necessary by the engineer in charge of the work. This was a wise provision, and would seem to be almost necessary in order to properly protect the interest of the city.

"This reservation did not mean that the commissioners could arbitrarily increase or diminish the quantities without regard to the actual amount of work or materials necessary to build the dam and reservoir. On the contrary, it was to protect the city against claims for loss of profits in case the estimated quantities were in excess of the amount actually required, and from claims for damage in case the actual quantities exceeded the estimates. In other words, the city, while it had taken every means known to ascertain in advance the actual situation, declined to guarantee the correctness of the estimates of the engineers, but left it to the bidders to satisfy themselves by a personal examination, and other means, as to just what would have to be done in order to complete and carry out the proposed contract.

"Under such circumstances it is not at all surprising that the bids should vary, because each would depend upon the judgment of the person making it as to the accuracy of the estimated quantities. The bidders, however, were all placed in the same position. They all had, or could have obtained, the same information. They knew what would be required and what would have to be done in order to comply with the contract, and for which they would be paid a stipulated price. This furnished just as much a standard of comparison as would bids for a lump sum. One bidder might have greater intelligence than another, and to this extent have an advantage, but, if the work had been let for a lump sum, he would have had the same advantage, and this advantage is the reward which intelligence always brings.

"The fact that MacArthur Bros. Co. and Winston & Co. made a nominal bid on certain items does not subject them or the Aqueduct Commissioners to any criticism. The reason which induced them to make such bids was a matter purely personal to themselves. They may have thought the estimates in those respects were erroneous, and the materials and work called for by these items would not be required. If they were in error, nobody was injured except themselves. There is nothing to indicate that there was any collusion between the successful bidder and the chief engineer of the commissioners.

*Award to High Bidder.*—"Finally it is claimed that the contract is invalid because it provides for the payment to the contractors of $165,892.60 in excess of the lowest bid, which, in fact, is a gift to them to this extent of public moneys which is prohibited by the Constitution of the State. It is true, as already stated, that the bid of the persons to whom the contract was let exceeded, by the amount above stated, a lower bid, but the act of 1883 did not require the Aqueduct Commissioners to let contracts to the lowest bidder. On the contrary, they were authorized to accept the bid 'which will, in their judgment, best secure the efficient performance of the work.'

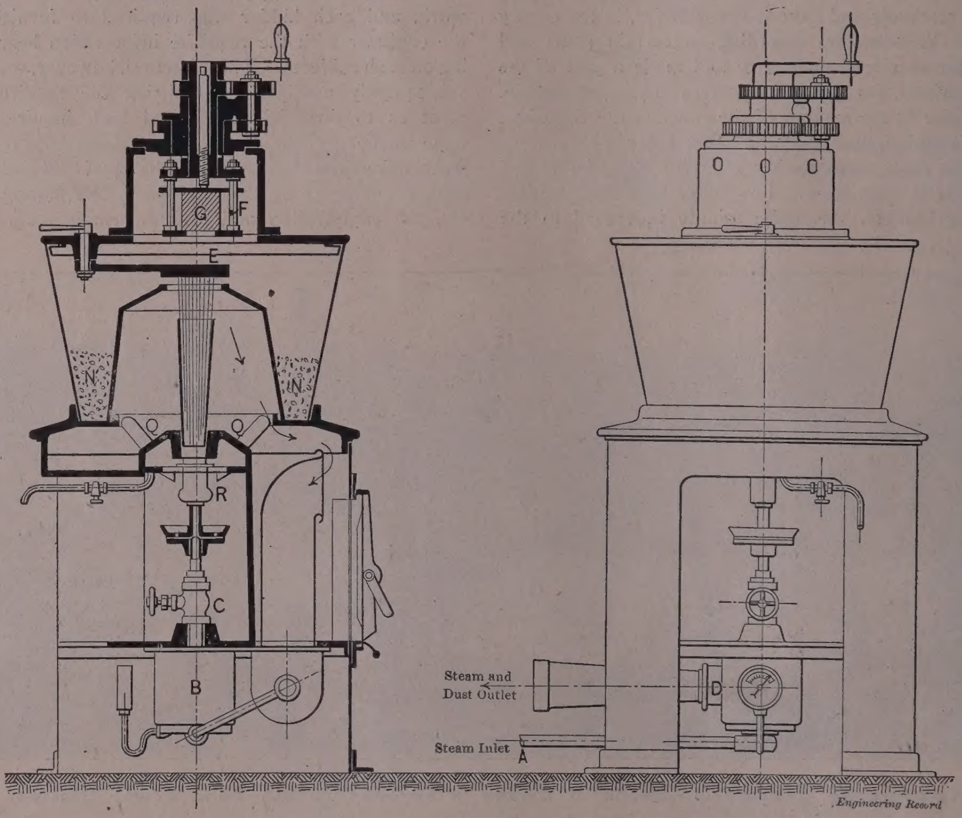
"Here time was of the essence of the contract. The city was short of water and the contract contemplated that work involving the expenditure of upward of a million of dollars should be done in a short time. The ability, therefore, of a contractor to do the work and fully perform the terms of his contract, was a very important consideration. The testimony shows that the Aqueduct Commissioners took this into consideration, and exercised unusual care in passing upon the bids. The engineers reported in favor of the ones to whom the contract was finally awarded, presumably because they had had experience in doing similar work and were prepared, so far as equipment was concerned, to immediately enter upon its prosecution. Besides, their bid was only about $60,000 higher than the average bid; was under the estimate of the chief engineer as to the cost of the work; and was considerably less than the highest bid, which was made by the only other person who had had actual experience in building works of this character."

## The Sand Blast for Testing Materials.

By H. Burchartz, Royal Testing Laboratory, Gross-Lichterfelde.

It is very important to select for construction purposes the best materials, more especially if they are used for paving roads and sidewalks or for covering floors. Besides the price, the durability of the material must receive due consideration, but it is not so easy to find a method of testing the wearing or abrasion of materials in a satisfactory and reliable manner and in a short time. While it is true that one can pave small tracts of a street with various materials and expose them to traffic, which would be the best method of determining their resistance to mechanical wear or the atmosphere, such practical experiments often last several years before the question as to which is the most durable and cheapest material is positively settled, and people cannot afford to wait such a long time.

Those in charge of technical investigations of paving and similar materials have therefore strongly wished to have a procedure requiring only a short time, but giving comparative results. The methods generally used for abrasion tests, either grinding specimens on cast-iron disks with corundum or treating the materials in tumbling cylinders (rattlers) with or without steel balls, do not give reliable results. The small parts of the material under trial which are separated in the grinding process increase the wear on some accounts, and on the other hand decrease it by filling the interstices of the material in the rattler, thus reducing the effect of the shocks. Moreover, the grinding material itself is used up, too; it being impossible to avoid using the same grains repeatedly, thus changing their shape and effect; and with soft elastic materials, the hard grains of the grinding powder partly penetrate the test piece, thus reducing the grinding effect, the grains now rubbing each other instead of touching the surface of the specimen protected by the grains fixed in it. The effect of these conditions is that the results obtained by means of the methods give no sure conclusion on the behavior of the materials under practical conditions.



**Apparatus for Testing Materials with a Sand Blast.**

Tests of Paving and Flooring Materials.

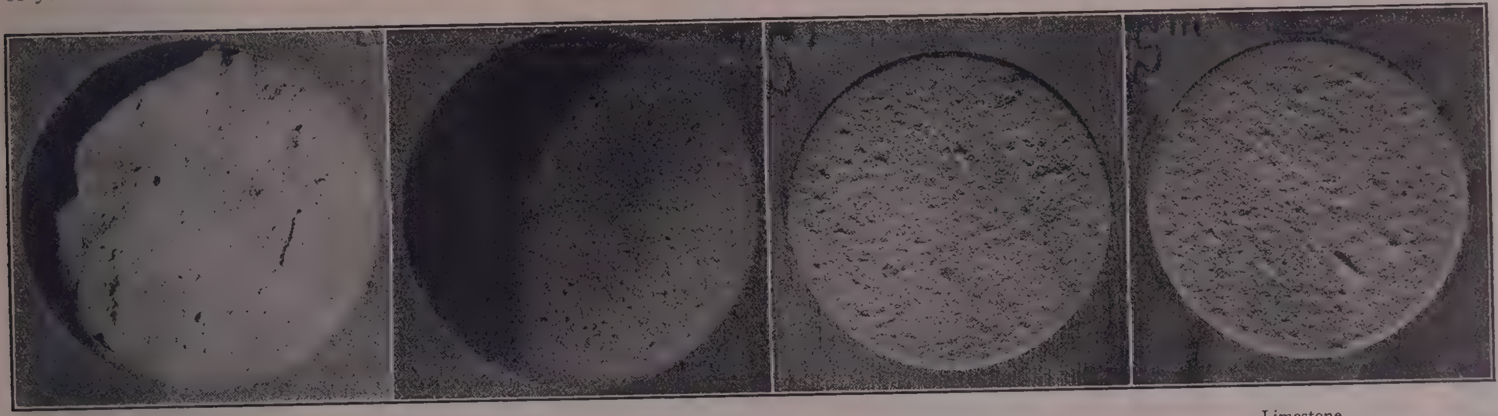
| Material and its source. | Weight of unit volume. Gr./c.cm. | Area tested—Bauschinger. | Area tested—Sand blast. | Loss in Bauschinger machine—Cubic centimeters. | Loss in Bauschinger machine—C.cm. per sq. cm. | Loss by sand blast—Grams. | Loss by sand blast—Cu. cm. | Loss by sand blast—C.cm. per sq. cm. |
|---|---|---|---|---|---|---|---|---|
| Granite | 2.615 | 50 | 28 | 5.1 | 0.10 | 6.91 | 2.64 | 0.09 |
| Pophyry | 2.444 | 50 | 28 | 8.6 | 0.17 | 8.14 | 3.29 | 0.12 |
| Trap | 2.605 | 50 | 28 | 12.4 | 0.25 | 11.07 | 4.24 | 0.15 |
| Slate | 2.679 | 50 | 28 | 29.7 | 0.59 | 21.49 | 8.02 | 0.28 |
| Sandstone | 2.214 | 50 | 28 | 42.5 | 0.85 | 48.41 | 21.87 | 0.77 |
| Limestone | 2.063 | 50 | 28 | 102.0 | 2.04 | 73.54 | 35.65 | 1.26 |
| Clay plates | 2.432 | 50 | 28 | 4.1 | 0.08 | 4.06 | 1.66 | 0.06 |
| Clinker plates | 2.126 | 50 | 28 | 7.4 | 0.15 | 11.47 | 5.39 | 0.19 |
| Paving clinkers | 2.146 | 50 | 28 | 13.1 | 0.26 | 9.64 | 4.49 | 0.16 |
| Blast furnace slag | 2.967 | 50 | 28 | 12.7 | 0.25 | 10.07 | 3.39 | 0.12 |
| Blast furnace slag | 2.717 | 50 | 28 | 14.4 | 0.29 | 11.40 | 4.30 | 0.15 |
| Granitoid plates | 2.419 | 50 | 28 | 12.4 | 0.25 | 11.05 | 4.57 | 0.16 |
| Concrete plates | 1.992 | 46.4 | 28 | 27.7 | 0.56 | 14.76 | 7.41 | 0.27 |
| Pine | 0.580 | 50 | 28 | 5.1 | 0.10 | 3.07 | 5.30 | 0.07 |
| Red pine | 0.448 | 50 | 28 | 9.5 | 0.19 | 2.28 | 5.10 | 0.10 |
| Red beech | — | — | 28 | — | — | 1.9 | The weight of volume is not determined for these four materials, therefore the loss of volume cannot be calculated. | |
| White beech | — | — | 28 | — | — | 2.7 | | |
| Oak | — | — | 28 | — | — | 2.0 | | |
| Pine | — | — | 28 | — | — | 1.6 | | |
| Linoleum, A. | 1.158 | 50 | 28 | 1.47 | 0.029 | 0.68 | 0.59 | 0.021 |
| Linoleum, B. | 1.131 | 50 | 28 | 1.77 | 0.035 | 0.75 | 0.66 | 0.024 |
| Floor coating | 1 598 | 50 | 28 | 20.4 | 0.41 | 14.30 | 8.95 | 0.32 |
| Hygiens flooring | 1.328 | — | 28 | — | — | 1.06 | 0.80 | 0.03 |

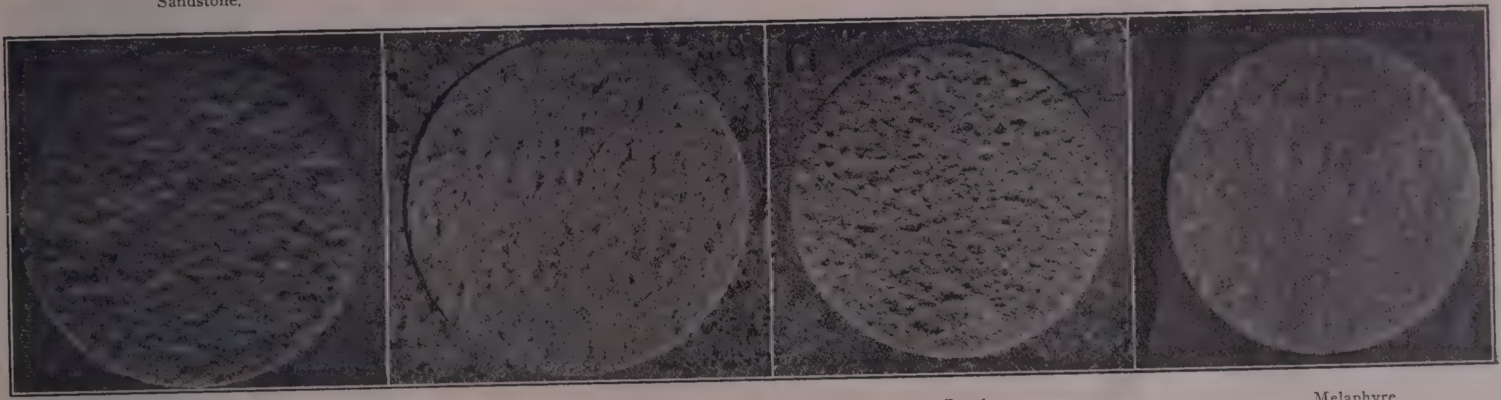
A new method of treating the materials, by which the difficulties and mistakes of the methods now in use are avoided and which possesses the great advantage that the grinding grain acts independently and each grain touches the specimen only once, is furnished by the sand-blast. The effect of the sand-blast is well known by the examples offered by Nature and by its various uses in some industries. What can be effected by the grinding influence of the sand blown by the wind during centuries is shown for instance by the renowned pyramid of Gizeh. How the dust and sand particles wear out and round off the edges and projecting parts of buildings in a series of years can be seen every day.

This slow action of the natural sand-blast is imitated in a much higher degree by the artificial sand-blast which is employed for making opaque glass and cleaning scale from the surface of rolled iron.

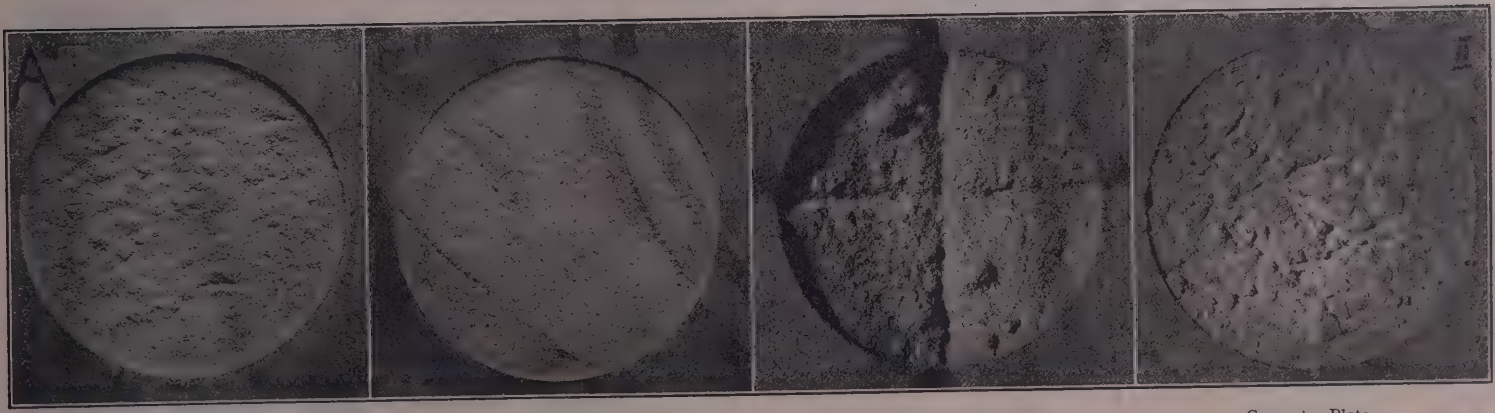
The sand-blast apparatus used for industrial purposes has undergone some changes in order to adapt it for testing building materials. Such an apparatus employed for abrasion tests in the Royal Laboratory for Testing Materials at Gross-Lichterfelde, Germany, is shown in the annexed figure. The working of this apparatus and its effect may be briefly described as follows, (See Gary, "Mitteilungen Kgl. Materialprüfungaamt," 1904, p. 103):

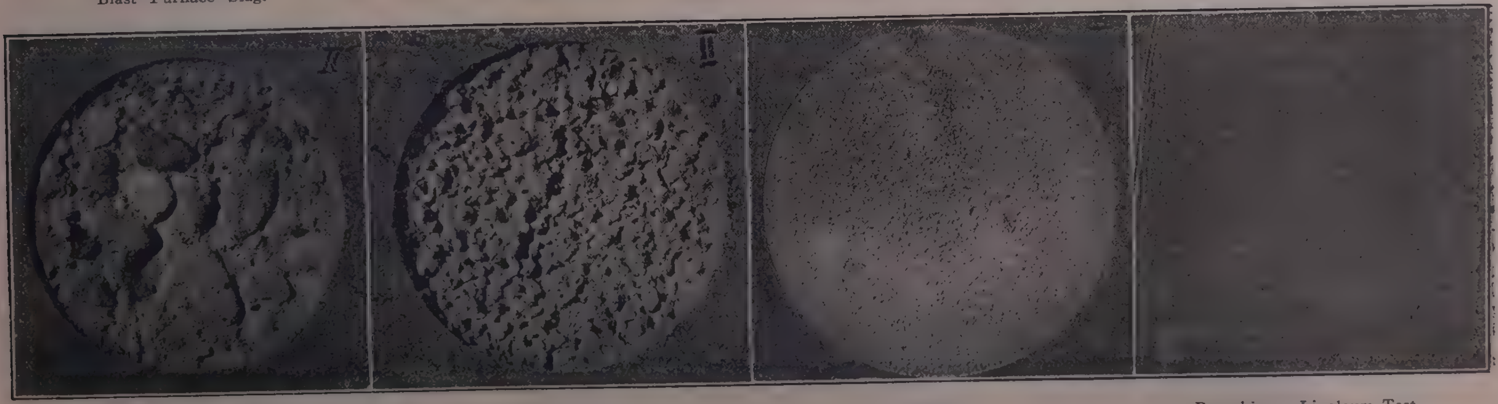
From the sand-chamber *n* the sand falls through small tubes *q* on to a plate and thence by small openings into a slit, where it is raised by the steam and blown upwards against the piece under test. The steam entering through the pipe is dried in the cylinder *b*. To shut off the steam from the apparatus a valve not shown in the


Sandstone. Sandstone. Melaphyre. Limestone.


Granite. Granite. Porphyry. Melaphyre.

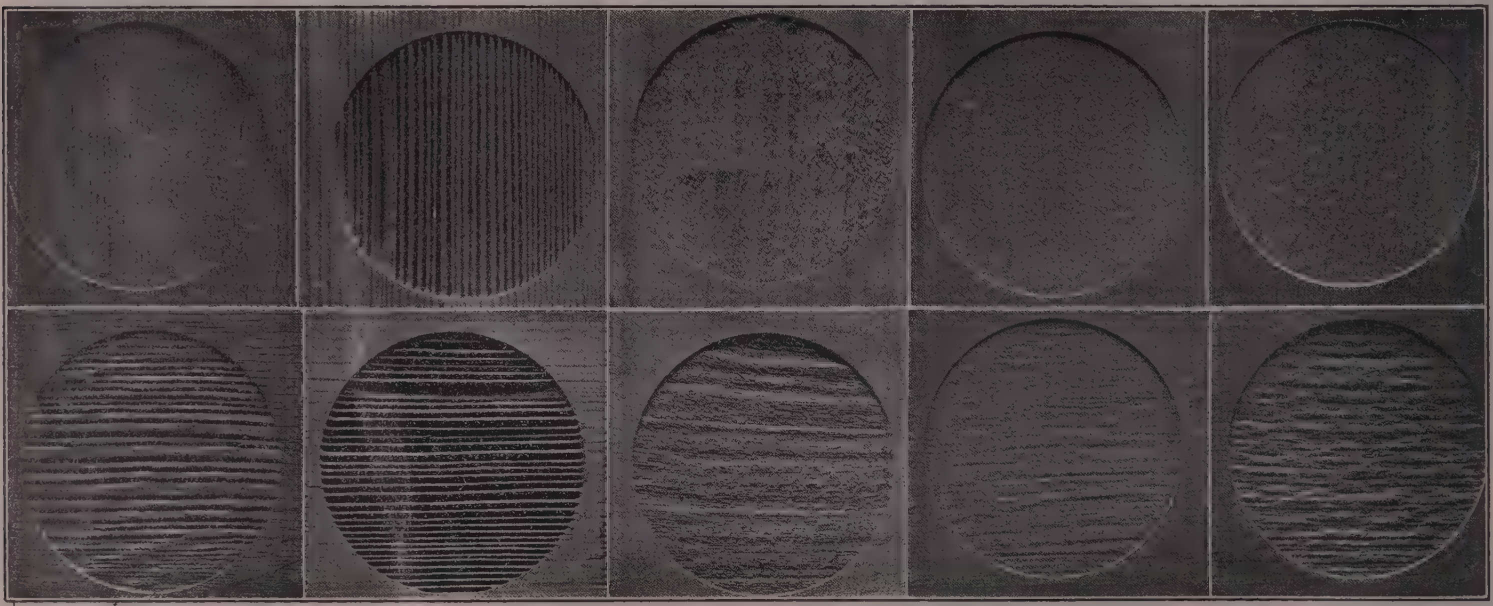
**Appearance of Pieces of Natural Stone Tested in Sand Blast.**


Blast Furnace Slag. Clay Plate. Cement Plate. Concrete Plate.


Concrete Plate. Artificial Stone. Linoleum. Bauschinger Linoleum Test.

**Appearance of Pieces of Artificial Materials Tested in Sand Blast.**

drawings is inserted in the steampipe. Another valve is placed at *c* and is to be closed for some minutes before using the apparatus, in order to heat it, as otherwise the sand would become wet by condensation; *r* is a valve for shutting off the sand. The steam and the dust from the sand being raised by the steam exhauster *d*, dry sand only is thrown against the specimen. The slide *e* allows the immediate stoppage of the sand stream. The testpiece *g* is fixed in the frame *f* and is moved over the sand-blast by turning the handle by means of a planet driving gear. Under the sample is placed a sheet iron templet with a round opening of 6 cm. (2.4 in.) diameter, and the sand-blast makes a deepening in the material only on this area of 28 sq. cm. (4.34 sq. in.). This deepening shows the quality and the characteristic properties of the material and the greater or less homogeneity of the different parts, the finer or coarser grain, the uniformity or the irregularity of the wear and, as a result, whether the constituents of the material are of equal or unequal hardness. It shows the thickness of the colored layer of burned plates and of the fine-grained covering of concrete plates as well as the fibrous structure of the various kinds of wood.



Oak. Pine. Poplar. White Beech. Red Beech.

**Appearance of Pieces of Wood Tested in a Sand Blast Apparatus.**

All these effects of the sand-blast on various materials will be clearly seen from the accompanying photographs. All these peculiarities and characteristics of materials are not revealed by the grinding or rattling process. By treating materials on a Bauschinger grinding disk, a flat surface only is obtained, as shown by the photograph of a specimen of linoleum tested on a Bauschinger machine; this photograph also shows the spots where the grains of the grinding material have penetrated the linoleum surface.

Some results obtained in the Prussian Testing Laboratory in abrasion tests made with different materials on the Bauschinger machine and by means of the sand-blast apparatus are given in the accompanying table. These few data sufficiently prove that the new method is most suitable for testing road and floor materials and gives good characterization with regard to their degree of wear in practical use and their quality. At the same time the test under the sand-blast gives valuable discoveries concerning the possibility of building materials.

The duration of the exposure to the sand-blast has been fixed at 2 minutes after many experiments, the steam gauge indicating 2 atms. pressure. This short time suffices to furnish a good indication of the structure of the materials tested and their resisting force.

The sand used in the Prussian Testing Laboratory is a natural quartz sand of fine and nearly round grains, gained by washing and drying the original sand and sifting it on a sieve with 120 meshes per square centimeter, or about 773 meshes per square inch (28 meshes per linear inch.) It is the waste from the preparation of the German standard sand used for testing Portland cement, the grains of which pass a sieve of 60 meshes and are retained on the sieve with 120 meshes per square centimeter.

The specimens are either cut out of the materials by means of diamond saws or formed in moulds if the material is made of a plastic mass like mortar.

The dried specimens are 7.1 x 7.1 centimeter (2.8 x 2.8 in.), or 50 square centimeters (7.75 sq. in.) in area. They are weighed before and after the exposure to the sand-blast.

The weight of a unit volume of the material, including interstices, is also determined. From the quotient of the loss in weight divided by the weight of a unit volume the wear in cubic centimeters is calculated and this figure is the proper value of abrasion for comparing the different materials.

The sand-blast apparatus is built by the Alfred Gutmann Co., Ottensen, near Hamburg, Germany.

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Laying Dust on Macadam Roads with heavy tar oil has been accomplished with considerable success in the Southall-Norwood district in England. About the middle of May of this year 9,000 sq. yd. of granite macadam were treated with waste tar oil obtained from a local gas works. The road was first thoroughly swept and all dust removed, then the liquid was applied to the surface from an ordinary sprinkling wagon, and well brushed in by manual labor. Since the first application, sprinkling with water has been unnecessary, and according to a communication to the Surveyor from Mr. Reginald Brown, the engineer of the district, the road surface is as good to-day as directly after the application. A number of branch roads have also been treated to give the liquid a fair trial. The results have been very satisfactory, as it is said that the dust has been laid; the noise of vehicular traffic is considerably modified; the road surface is preserved, and after a rain its appearance is that of a tar-macadam road—at a much less cost than the latter.

## A Municipal Generating Station in London.

An electric generating station, the ultimate capacity of which will be 52,000 h.-p., was recently formally opened for operation by the London County Council. This station will supply power to the London municipal tramway system, power for the tramways having been purchased from local companies until the station was completed. The station comprises a boiler-room, engine-room, a sub-station, workshop, pump and strainer houses, offices, outside coal bunker and a pier along the Thames River on the bank of which the station is located. The station building will be 195 x 475 ft. in plan and 80 ft. high when completed. It has a steel frame and brick sidewalls and is built on a heavy concrete footing.

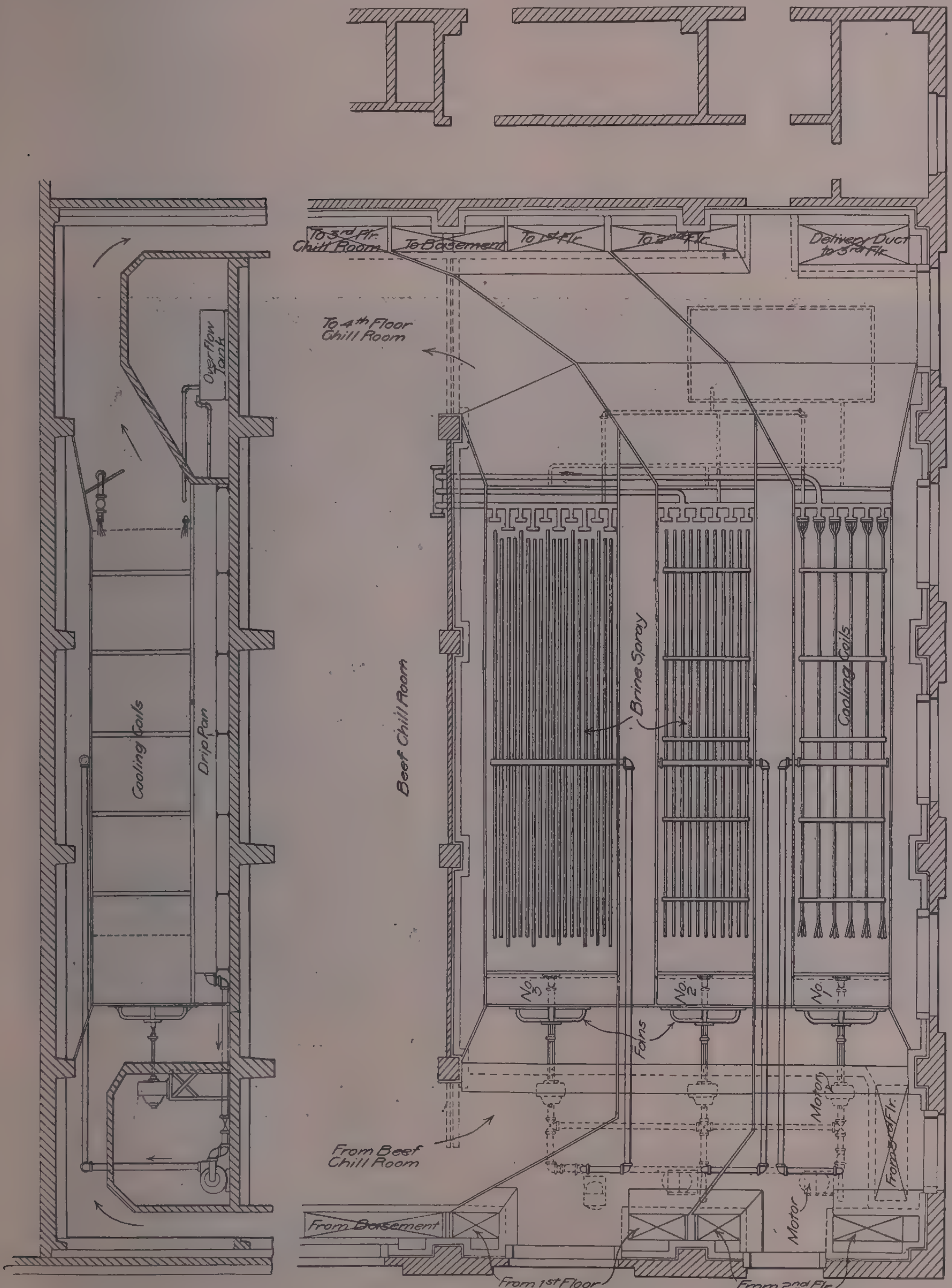
The boiler-room contains 24 water-tube Sterling boilers of the five-drum type, with a combined capacity of 26,000 h.-p.. A superheater is placed between the first and second banks of vertical tubes of each boiler and forms an integral part of the latter, the amount of superheat being 500 deg. Fahr. Each boiler has a separate economizer on the floor above. Above the economizers at the top of the building are steel coal bunkers having a capacity of 6,500 tons. These bunkers are supplied from the pier along the river by gravity bucket conveyors having a combined capacity of 80 tons an hour. The ashes are also handled by these conveyors on the return trip. The feed-water pumps, feed-water purifiers and hot wells are in the basement of the boiler house.

The engine-room is parallel to the boiler house and contains four steam generating units of 3,500-kw. capacity each. The engines are of the vertical-horizontal type, each engine comprising two complete half-engines, one on each side of the generator, consisting of a vertical high-pressure cylinder 33½ in. in diameter, and a horizontal low-pressure cylinder 66 in. in diameter. The engines are all enclosed, working at 94 r.p.m. with forced oil lubrication, for which pumps are provided in duplicate.

The generators are of the revolving field type, and deliver three-phase current at 6,600 volts between phases, at 25 complete cycles per second. The normal output of each generator is 3,500 kw., with provision for 4,375 kw. on emergency overload. The generators are mounted directly on the engine shaft. The 6,600-volt, three-phase current is transmitted to various sub-stations, where it is stepped down to 550 volts direct current by rotary transformers.

## Refrigeration System of the Model New Abattoir in New York City.

The new abattoir of the New York Butchers' Dressed Meat Co., at 39th St. and Eleventh Ave., New York, the mechanical equipment and construction of which have been described in the two preceding issues of this journal, has extensive provisions for cold storage, the refrigerating system for which has been designed with special reference to the sanitary storage and preservation of the dressed meats. The cold storage rooms occupy the greater portion of the main abattoir building, from the basement to the fourth floor inclusive, embracing over 27,000 sq. ft. of floor area. Two rooms upon upper floors are devoted solely to the chilling of freshly killed cattle to remove the blood heat before entering the main cold storage, while the remainder are for general cold storage at low temperatures. The rooms are cooled by an indirect system, embracing cooling coils upon an upper floor over which air is blown by fans and delivered to the coolers through ducts, the system being made more effective by brine sprays maintained over the coils, both to prevent formation of frost and ice on the coils and to wash and purify the air delivery to the coolers.



**Details of the Air Cooling Apparatus of the Abattoir Cold Storage.**

The coolers are distributed upon all of the lower floors of the abattoir building and the basement, embracing a chilling room upon the fourth floor, a chilling room and two coolers upon the third, two large coolers upon the second, and a salesroom cooler both on the first floor and in the basement. The chilling rooms consist of a 35x80-ft. room on the fourth floor, in the central portion of the building, and the westerly one of the three cold storage rooms on the third floor below; the latter room is 37 x 80 ft. in plan, and both have an interior finished height of 11 ft. 9 in., the combined volume of the two chilling rooms thus amounting to 67,680 cu. ft. The remaining cooling rooms of the building which are operated for general cold storage of meats consist of two 35x80-ft. rooms occupying the remainder of the third floor, having a combined volume of 65,800 cu. ft., two coolers upon the second floor, one 36 x 80 ft. and the other 53 x 80 ft. in plan, having a combined volume of 83,660 cu. ft., a large single salesroom cooler upon the first floor, 65 x 72 ft. in plan, and also a single cooler, 52 x 80 ft. in plan, in the basement for a small stock storage, these two rooms together having a volume of 103,090 cu. ft. These cooler rooms are all heavily insulated with Nonpareil cork insulation which has been installed according to a special system by the Nonpareil Cork Works of the Armstrong Cork Co.; special care was given to this feature of the refrigeration system, the insulation having been made continuous upon all sides, ceiling and floors of every room, there being no joints between the insulation and the steel work or concrete at any side or corner, where a crack or opening may form at a later time and admit warm air to impair the efficiency of the system. The details of the cork insulation are referred to in an article in a previous issue of this journal descriptive of the details of construction of the abattoir building.

The arrangement and details of the air coolers and the auxiliary brine spray equipment which are located on the fourth floor, are shown in an accompanying drawing. A section of the fourth floor of the abattoir building, 36 x 80 ft. in plan, at the easterly side is devoted to this equipment, which is arranged in three longitudinal groups of cooling coils and sprays; these occupy the entire central portion of the room, while the independent blowers and their motor drives and the motor-driven brine circulating pumps for each group are located in an enclosure at the southerly end. In a space of 17 ft. between the cooling coil enclosures and the vertical air-delivery ducts at the northerly end of the room is a brine overflow tank for the brine-spray and air-wash systems. The coil groups are arranged with 30-in. passages between them and 18-in. passages next to the side walls, the two outer groups of coolers, Nos. 1 and 2, being 7½ ft. in width, while the inner cooler, No. 3, is 10¼ ft. wide. The groups of coils are 32 ft. in length while the steel-plate enclosures surrounding them, through which the air is circulated, are 40 ft. in length by 7½ ft. high inside above the catch basin. Thus three distinct systems are arranged with independent duct connections to supply different groups of cooling rooms on floors below, all entirely separate from each other, so as to enable any section to be cut out of service for necessary inspection and attention, while cross connections have been provided so that any of the air coolers may serve any or all of the cold storage rooms at the same time.

The cooling is on the American Linde system, and is accomplished by forcing the air against the direct ammonia expansion coils, over which a spray of brine solution is continually flowing. The coils are made in one continuous length of about 300 ft. of 1¼-in. extra heavy wrought-iron tubing bent zig-zag, so as to avoid joints. These pipes are bent before shipment. Each section consists of three of these coils mounted on structural steel frame work, the entire group suspended above a brine drip pan. Each coil is connected at top and bottom with ammonia headers and manifolds with mains to and from the engine room. Air coolers Nos. 1 and 2 each have six sections with capacity rated at 60 tons refrigeration, while cooler No. 3 consists of ten sections and has a capacity of 100 tons.

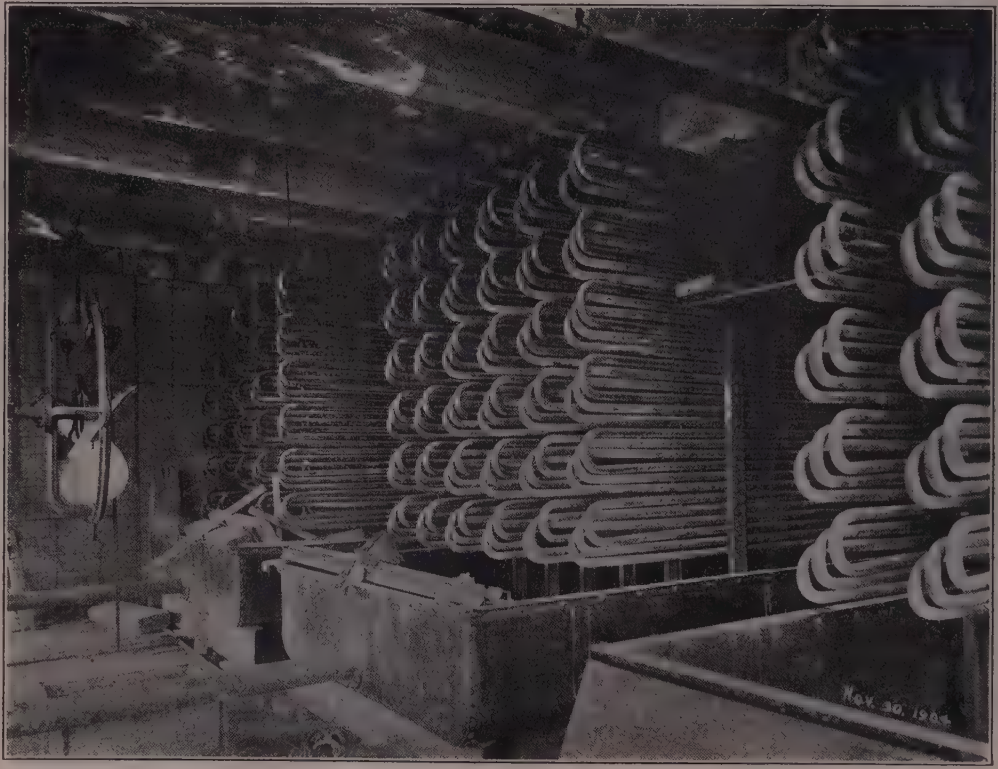
Brine is circulated over the cooling coils by means of perforated spray pipes which are mounted over them in continuous lengths, 31½ ft. long, 11 spray pipes being provided over each of the smaller 6-section groups of coils and 19 spray pipes over the larger 10-section group. The spray is caught in drip basins below the coils, the brine circulation being operated for each air cooler by a 4-in. centrifugal pump, which takes suction from the drip pan through a 5-in.

suction line and delivers by a 4-in. main to the spray piping above the coils. Each pump is driven by a 10-h.-p. General Electric motor, fitted for speed variations by field control for convenience in operation of the system. These pumps and their motor drives are located in an enclosure at the south of the coolers in which the fan motors are located, and thus are not exposed to the circulating air. The suction connections from all three drip pans are interconnected by a 5-in. cross header in the motor room close to the pump suction connection, so that any pump may serve to draw from any of the other drip pans. The perforated spray pipe is all of 1½-in. pipe, each length capped at either end and fed by down connections from a manifold header across the middle and each pipe is supplied through a 2-in. valved connection so that it may be cut out of service if desired. The spray drip tanks are in all cases 37½ ft. in length by 2 ft. in depth, those of coolers No. 1 and 2, 7½ ft. wide, and that of cooler No. 3, 10¼ ft. wide. They are built of ¼-in. steel plates and are supported 12 in. above the floor line by 12-in. I-beams spaced about 6 ft. apart. The enclosure confining the air blast from the fan to the air cooling coils serves to catch the spray; at the delivery duct end is an inclined apron, 11 ft. long, leading up to the ceiling duct connection which catches the spray carried out with the moving air and returns it to the drip tank, thus preventing any moisture from reaching the cold storage rooms through the duct system.

Owing to the tendency of the warm air entering the cold storage rooms due to opening of doors, and the vapors given off by the carcasses, to part with moisture when subjected to the low temperatures of the air coolers, considerable water is added to the brine by condensation from the air circulation being intercepted by the spray, and for this purpose an overflow tank is provided in the cooling coil room into which the brine is discharged when the drip pans are filled to a height of over 16 in. To provide for this continual dilution of the brine solution, a system of brine concentration has been installed on the fifth floor consisting of tanks with steam coils into which the brine is pumped from the overflow tank and boiled until reduced to the proper density again, after which it is returned by gravity to the spray system. In this way the continual addition of calcium chloride, which is used for the brine solution instead of common salt, to the solution with continual waste of the excess liquid is avoided.

The air circulation through the coolers is supplied by a 60-in. Sirocco propeller type fan for each group of coils, the fan being driven by an individual 15-h.-p. General Electric motor, mounted outside of the duct enclosure, and connected to the fan by an extended shaft and flexible coupling. The motors operate at 300 r.p.m. and have 25 per cent. speed ranges by field control. The fans each have rated capacities of 28,000 cu. ft. per minute, delivering at a velocity through the cooler casings of approximately 550 ft. per minute. The free area for passage of the air blast through the coils is approximately 50 sq. ft., while the delivery ducts average 4½ x 10 ft. in cross section. The air coolers are housed in steel-plate enclosures connecting at their southerly ends with vertical suction ducts that exhaust from the cooling rooms below and at the northerly ends with vertical ducts leading downward to the rooms supplied. The duct connections have dampers interposed between them by means of which either air cooler may deliver into any of the other delivery systems in case one air cooler is shut down. All this duct work, and, in fact, the entire room in which this equipment is located is insulated with Nonpareil cork board covering applied in a manner similar to that used in the cooling rooms.

The arrangement of the direct duct connections from the air coolers to the cold storage rooms, is such that cooling coil No. 1 supplies the salesroom coolers on the first floor and in the basement, cooling coil No. 2, the cold storage rooms on the second floor and the two easterly rooms of the third floor, and cooling coil No. 3, the two chilling rooms, one at the westerly side of the third floor and the other on the fourth floor, adjacent to the refrigerating machinery room. The enclosures surrounding the cooling coils are of No. 12 galvanized steel, while the duct connections, including both the vertical ducts and the horizontal branch connections from them above the suspended ceilings of the cooling rooms to the distribution outlets, are all of No. 20 double galvanized steel plate. The interconnections between the three systems consist of by-pass dampers in the partitions between the horizontal delivery ducts from the air cooler enclosures which may be opened and closed from below. The vertical ducts have tight-closing dampers at each branch to a cold storage room by means of which any room may be entirely cut out of service if desired. Similarly the distribution outlets in the ceilings have dampers by means of which the flow of chilled air into any portion of the room may be adjusted as desired. The result of this arrangement is that the degree of refrigeration in any particular room may be varied as desired without affecting that of the others supplied from the same cooling coil, or changing the cooling capacity of the coil. It is, in fact, found possible to adjust the temperature in any cooler, by thus throttling the supply to that room, up to 35 or 40 deg. Fahr., or higher, while all the other rooms supplied from the same cooling coil, are maintained at 30 deg. Fahr.



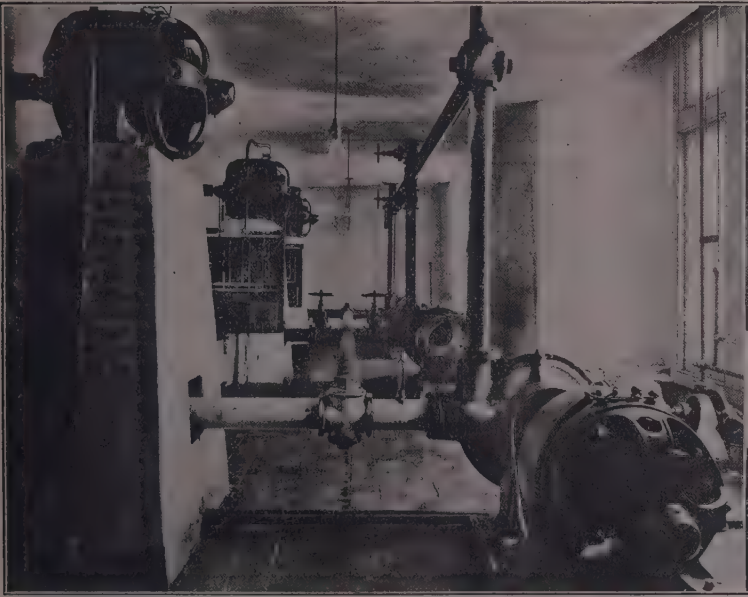
**Construction View of the Cooling Coils and Fan.**

The arrangement of the supply and exhaust connections in the ceiling of each cooling room is such that chilled air is delivered along the two sides while the warmer air exhausted is taken from the middle. The inlet and outlet registers are openings through the ceiling insulation construction to the branch ducts above, which openings are 12 in. square, spaced from 4 to 6 ft. apart, as required. The dampers are the double-leaf type and are tight closing and easily operated from the floor, so that the direction and amount of flow in all parts of any room is easily controlled. The branch ducts which are carried above the suspended ceilings of the cooling rooms are wide flat ducts from 10 to 12 in. in depth according to the volume of the room supplied, and varying in width from 4 to 12 ft.

The duct work is proportioned to allow the delivery of the fans at the maximum capacity to flow at a velocity of not over 400 ft. per minute, at which rate, when all cold storage rooms are in service, the air in them is changed fully ten times per hour. Under ordinary conditions of operation, however, except in the hottest summer weather, the 100-ton cooling coil, or any group of two of the coils is capable of handling the entire system. Throughout the moderate weather of the spring one of the 60-ton air coolers has proven sufficient to maintain the desired temperatures in all cold storage rooms of the building, the air being changed in the rooms under these conditions about four times per hour. This operating condition is indicative of much greater economy than was even hoped for, which is due, without doubt, to the careful and effective installation of the cork board heat insulation.

*Operation.*—The mode of operation of the plant for which this equipment was designed and laid out provides for the highest standards of sanitary handling of dressed meats. It is arranged so that on the killing floor, all carcasses, after being dressed, are thoroughly washed with clean water, the purpose of which is at the same time to partially remove the animal heat; the halves are then passed to the inspection area of the rear of the killing floor, where they cool further, and by a thorough ventilation of this floor the meat is there dried before being taken to the chill rooms. Before placing the meat in cold storage, it is essential that it be chilled gradually, as if meat be placed in cold storage room before the animal heat has had time to pass out of the carcass, the outside of the carcass chills too rapidly, preventing the escape of the animal heat from the inside, with the result that what is known in the trade as "bone stink" inevitably takes place, and renders the meat unsalable. The chilling rooms of this plant are therefore arranged to be kept at temperatures of 40 deg. Fahr. or above, so that the meat is chilled very slowly, allowing the animal heat and gases to pass out thoroughly.

As soon as the beef is completely and evenly chilled to the temperature of the chilling room, it is removed to the coolers on the third and lower floors for the cold storage, which rooms are kept usually at temperatures of from 30 to 35 deg. Fahr. The beef leaves the chill rooms at a temperature of about 40 deg. Fahr., or slightly above, and thus in transferring to the coolers after about 24 hr., is given the opportunity to cool gradually and thus very evenly to the lower storage temperature which places the meat in best condition for storage. It is found in practice that the meat thus cooled has been kept in storage for eleven weeks without the slightest injury, although where meat is to be kept for a number of weeks it is the practice to transfer it to a separate cooler, which is kept at a temperature as near as possible to 32 deg. Fahr., and in general to avoid placing freshly dressed beef in rooms with beef that has been dressed for a number of weeks. The beef is not frozen when kept at 32 deg., as it requires a temperature of 28 deg. to freeze beef, but it is found that at a temperature of 32 deg. the meat cooled under these conditions will last almost indefinitely. The great advantage of separating the freshly killed and older beef is that the moisture and gases given off by the freshly killed beef cannot then be communicated to the older meat and the accumulation of the usual mould or fungus growth on the latter is thereby prevented.



**Fan Motor Drives and Brine Circulating Pumps.**

**Delivery Duct Connections from Air Coolers on Ceiling.**

The method of temperature regulation in the chill rooms and coolers consists primarily of adjusting the flow of ammonia through the pipes of the air cooler coils on the fourth floor, which is accomplished by the expansion valves of which there is one for each section of the cooling coils; in this way the temperatures of the pipe coils are easily varied and that of the brine spray quickly follows, as the brine is sprayed continuously over the coils. For further adjustment of the temperature of any of the cooling rooms, the dampers may be operated, the partial shutting off of any supply duct having the effect of lowering the temperature in the room supplied. It is figured that the brine on the cooler supplying the chill rooms should ordinarily be maintained at a temperature of 25 deg. Fahr., at which the chill rooms under present conditions of operations will hold at a temperature of about 40 deg. Fahr. At present the plant is being operated at much less than its full capacity and considerable regulation is required to maintain the chill rooms at the desired temperature. For the other cooling rooms, the brine is kept down to 15 deg. Fahr., with the result that the temperatures in them are thereby maintained in the vicinity of 30 deg. Fahr.

While the purpose of the brine spray of the American Linde system is primarily to maintain the cooling coil free from the ice and frost that would otherwise accumulate on them due to the freezing of the moisture condensed from the air, it also incidentally serves an important hygienic advantage in washing and purifying the air, and, at the same time, in regulating its humidity. The general design of the air coolers is such that they closely resemble the air-wash apparatus which is at present coming to be very generally used in ventilating systems for the purification of air delivered into buildings, except that here the extent of the spray is very much greater in proportion to the volume of air passed, the spray jets being continuous throughout the entire length of the cooling coils. The air is thus brought in most intimate contact with the brine solution so that in addition to being chilled, it is thoroughly cleansed of all odors and impurities. In tests that have been made with this type of cooling system, refuse giving off the most offensive odors have been placed in the air suction connections and yet upon the delivery side of the cooler the odor which was almost unbearable at the other end, could not be detected.

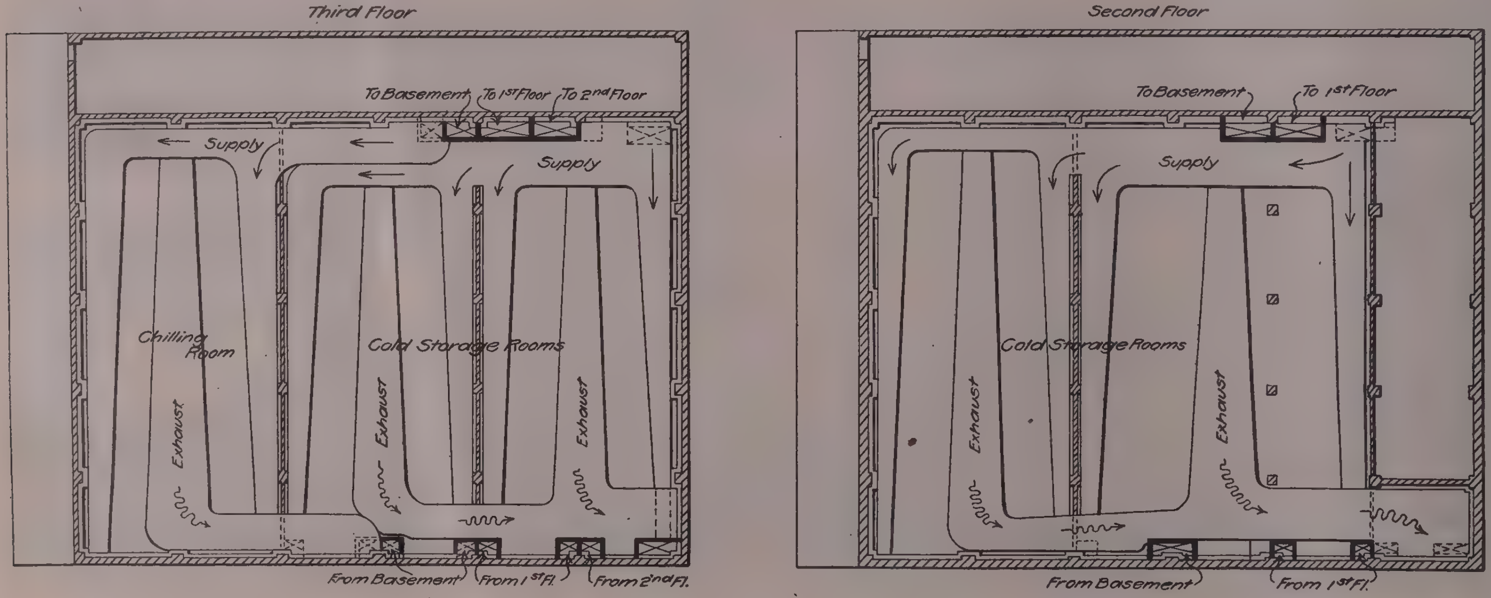
The regulation of humidity is of particular value in the storage of meats for preventing the growth of mould and fungus which occurs with ordinary storage systems where the air in the cooling room inevitably becomes super-charged with moisture condensed from the air. The tendency is for the air which finds its way into the coolers and the vapors given off by the carcasses to part with its moisture due to the lower temperature encountered. The brine spray, however, intercepts this moisture and retains it, so that only the saturated air continues, which is found to be sufficiently dry to absolutely prevent injury to the beef stored. The vapors given off from the beef are also thus subjected to the brine solution, which in addition to regulating the humidity, removes contamination which is most effective in preventing mould growth on the meat.

*Refrigerating Machinery.*—The ammonia compressors for the operation of the cooling coils are located in the power plant building which adjoins the fat-rendering building to the westward and consists of a 250-ton refrigerating plant made up of two ammonia compressor units, one of 100 tons capacity and the other of 150 tons capacity. These compressors are both Vilter horizontal double-acting compressors, with water-jacketed compressor cylinders and valves located in the cylinder heads. The smaller unit has a compressor cylinder 16 in. in diameter by 32 in. stroke, while that of the larger machine is 19 x 38 in. The plunger stuffing boxes have self-adjusting metallic packing and long hollow sleeves through which oil is circulated both for lubricating and cooling the plunger rod and also sealing the ammonia against escape.

The steam ends of the compressor units consist of tandem-compound condensing Vilter Corliss engines, the smaller unit having 15 and 28x36-in. cylinders, while those of the larger unit are 16 and 30 x 42 in. in size. Both engines have intermediate receivers between high and low-pressure cylinders, which are located below the floor in the basement with short direct connections. The larger unit has a 24,000-lb. flywheel, 16 ft. in diameter, which is mounted on a 12-in. main shaft, while the other machine has a 17,000-lb. wheel, 14 ft. in diameter, mounted upon a 11-in. shaft. Further details of this equipment will be presented in an article descriptive of the power-plant installation to be published in a subsequent issue of this journal.

The ammonia connections are of unusually strong construction, involving extra heavy wrought-iron pipe with fittings of steel castings, mounted with metallic packing, all valves and fittings having been tested to 300 lb. In the ammonia delivery piping there is an oil trap and receiver by means of which the liquid ammonia is freed of the oil which it entrains from the cylinders of the compressor, and by means of the receiver it may be drawn out at suction pressure. The ammonia delivery is carried thence to the roof of the building to an ammonia condenser consisting of 10,000 ft. of 2-in. standard-weight galvanized pipe for the atmospheric cooling of the liquid ammonia as it is delivered from the compressors under high pressure. The coils are built twenty-four pipes high with a shut-off valve on each section, and also has a section pumping-out system, complete with valves, for removal of ammonia in case repairs are necessary. They are protected by a light canopy on the roof and have over them a series of water jets for spraying to assist in cooling. Salt water is used for this purpose, a wooden tank, 10 ft. in diameter and 12 ft. deep, on the roof the fat-rendering house adjoining furnishing gravity head for the sprays. The drip is caught in a pan beneath the coils, 26 x 38 ft. in plan and 12 in. deep, from which it is returned to the roof tank by a 400-gal. centrifugal motor-driven pump located on the top floor of the power house; this motor is a 30-h.-p. General Electric motor, equipped for variable-speed operation by field control, for convenience of adjustment to operating conditions.

The refrigerating equipment, and the details of the heat insulation, were designed by Horgan & Slattery, New York, who were architects for the building construction and also engineers for this equipment. The cooling plant was built and installed by the American Linde Refrigerating Co., New York. The compressors and engines were built by the Vilter Mfg. Co., Milwaukee, Wis., and the ammonia piping was installed by the York Mfg. Co., York Pa. The air duct work was installed by the A. J. Ellis Co., New York, and the water piping, tanks and other details of the auxiliary equipment by the E. Rutzler Co., New York.



**Arrangement of Delivery and Return Duct Connections to Cold Storage Rooms on Floors Below.**

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Repairing Breaks in the Hull of a Sunken Ship with concrete was carried out in the salvage of the screw-propeller steamer, George W. Elder, in the Columbia River. The boat sunk on jagged rocks in 16 ft. of water on Jan. 21, 1905, stoving several holes in her iron hull, the principal one of which was 84 ft. aft of the bow, running aft. The hole extended 36 ft. fore and aft and 34 ft. athwartships and was made by a rock which projected 10 ft. 8 in. up into the hold. A bulkhead was built fore and aft of the break and two aft of the engine room. Heavy canvas was then laid over the rock which projected up into the hold. Concrete was placed over this canvas until the hole was closed. A 1.5x4x33-ft. concrete beam being built athwart the hold to carry the concrete, closing the hole. The concrete was mixed and placed under water by divers, the cement being sent down a chute in sacks and the stone in a box. Another break was also filled with concrete, after which the hold was pumped out and the vessel floated and towed 40 miles to a dry dock.

## New Sand-Lime Brick Plant at South River, N. J.

An extensive plant for the manufacture of sand-lime brick under the Huennekes system has been completed at South River, N. J., by the New York Granite Brick Co. The plant has a capacity of 100,000 bricks per day, and is the largest sand-lime brick manufacturing plant that has yet been built. A particularly favorable location was secured at South River, where an almost unlimited supply of clean, sharp, white sand is available, and in addition, the plant is convenient to both rail and water shipment. Water shipment is made by barges to the New York City market via the Raritan River, while connections to the Central R. R. of New Jersey permit trunk line railway shipments.

The process of manufacture is that of the Huennekes system, which has come into extensive use in this country, there being over thirty factories in operation. The process involves, in brief, the grinding and intimate mixture of sand and lime ingredients, and subsequent hydration, after which the bricks are moulded under heavy pressure and hardened. The hardening is accomplished by subjecting the brick to steam pressure for a number of hours, after which they are ready for shipment and use without burning, further aging or treatment. Extensive tests made of this type of brick in Germany have indicated that in strength and fire-resisting qualities, it is the equal, if not superior to the best clay brick, whereas in durability it is comparable to granite and limestone. The brick are capable of being tinted in almost any color and moulded in any form. A feature of this type of brick is the possibility of controlling the percentage of absorption of moisture, which may therefore be kept as low as desired. In point of strength and durability, this type of brick compares extremely favorably with other types. In recent tests made at the Columbia University testing laboratory for the New York Building Department, the results of crushing, transverse, absorption and other tests prove universally above the requirements. In compression they showed an average ultimate strength of 4,784 lb. per square inch; in breaking, an average modulus of rupture of 651.2 lb. per square inch, and an average absorption of 14.2 per cent. In both the freezing and fire tests they also proved more than unusually serviceable.

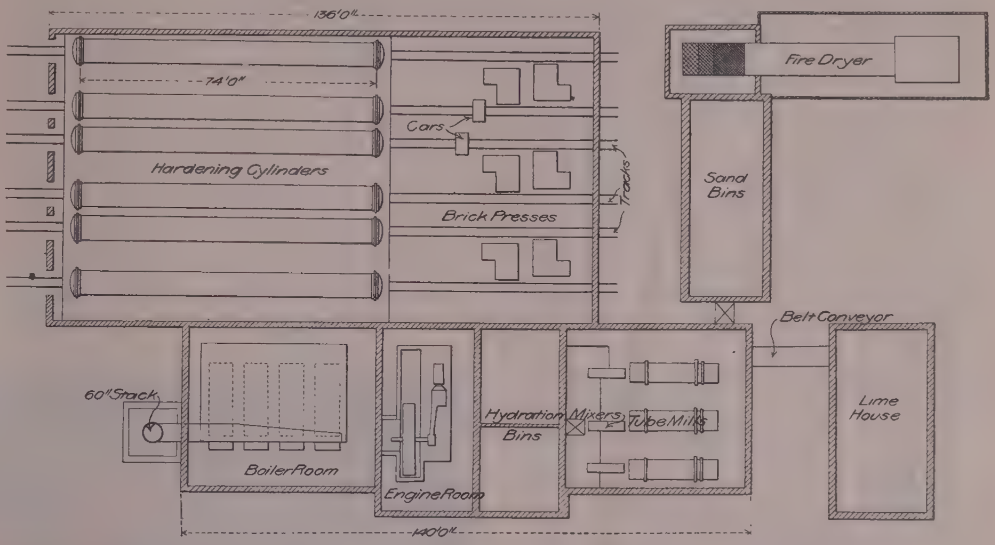
In the process of manufacture the sand is hauled and delivered, as it comes, in a damp condition, from the bank, to a rotary fire drier, which consists of a rotating steel cylinder lined longitudinally with blades. In passing through this cylinder the sand is constantly elevated by the blades and showered down through a blast of hot air, which is forced through by a fan, and removes the moisture that the sand contains. At the depositing end of the cylinder is a rotating screen of proper mesh to allow sand only to pass through, discharging the gravel and foreign matter over the end. The sand is then raised by an elevator to a large storage bin of special design, from which it is conveyed by belt and elevator to a hopper. Immediately under this hopper is arranged a rotating feeder which feeds a correctly measured amount of sand that is promptly divided into two parts varying in proportion; the lesser part falls into a chute that conveys it directly into the receiving end of the tube mill, while the larger quantity is conveyed on a belt over the tube mill to the delivery end. It is discharged from that end into a blade or paddle mixer, together with the pulverized portion, which, with a small percentage of lime, is ground by the rotary motion of the pebbles in passing through.

The lime used in the process is made from calcium limestone bearing a chemical analysis of at least 90 per cent. lime. It is received in lumps as it comes from the kilns, and is first crushed and reduced to a fine powder to pass through a ⅛-in. mesh screen, and then elevated to a bin. From this bin it is conveyed to a hopper located by the side of the sand hopper. Under the lime hopper is a feeder connected to the same shaft driving the sand feeder, and by automatic measuring conveys accurately any quantity of lime required, usually about 5 per cent. The lime fed in this way is discharged into the same chute as the portion of sand which is to be ground, and with it on the same conveyor passes into the tube or pebble mill where both are ground together in their passage through the mill, thereby forming a sand-lime powder which will pass through a very fine mesh screen. In the tube mill the sand can be reduced to any desired fineness in order to produce any texture of brick, either coarse-grain or fine face, regardless of the original texture of the sand. When this finely ground sand and lime leaves the discharge end of the tube mill, it is delivered into the blade mixer where, as stated above, it joins with the larger portion of unground sand and is thoroughly mixed with it, filling all the voids or interstices between the larger grains of sand.

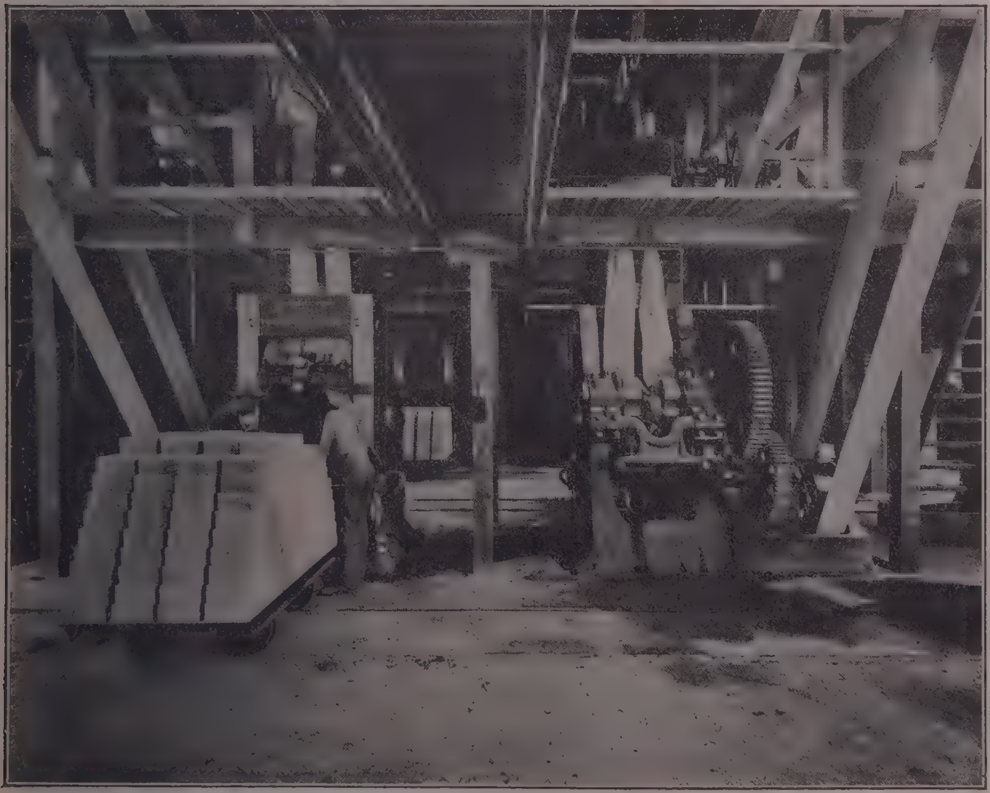
In the first half of the mixer the sand and lime are thoroughly mixed dry, each particle of sand being completely covered with lime dust, and in the second half the quantity of water necessary to slake or hydrate the lime thoroughly in the sand is added, thereby beginning the formation of the bond. After this very complete mixing the sand-lime material is elevated to a hydration bin, with sufficient capacity to supply the factory for one day, and is allowed to remain in this bin for twenty-four hours. The following day the material is drawn from the hydration bin on a conveyor belt and is discharged into a spiral feeder and conveyor-mixer, which conveys it to the presses in a regular measured quantity, opportunity being allowed while in the conveyor-mixer for the addition of moisture, if necessary, so that the material will be in perfect condition for the presses.

The material is then pressed into form by special four-mould brick presses, each brick being submitted to a pressure of 350,000 lb., after which the moulded bricks are placed on small cars which have a capacity of about 900 each. The bricks are laid in tiers on these cars and the tiers stacked one above the other, the bricks being strong enough as they come from the press moulds to withstand the weight of a person standing on them without crushing or cracking. The bricks are transferred on these small cars to large steel cylinders for the hardening process. The cylinders are built with removable heads at both ends. The heads, which are of heavy steel construction, are supported by cranes built on top of each end of the cylinder, to obviate manual labor in lifting when removing or replacing. After the cylinder heads have been swung into place, closed and securely fastened, steam is turned on and they are held under a pressure of 125 lb. per square inch for about 10 hr., this work usually being done at night. In the cylinder a proprietary compound is deposited in such a manner that the steam as it enters is thoroughly impregnated, which results in the proper hardening of the brick—a chemical action taking place which forms a tenacious and uniform bond.

After they have been submitted to the steam for a sufficient length of time, the head at the discharging end of the cylinder is removed and the entire trainload of cars is hauled out all at once, and, after a few hours' cooling, the bricks are ready for the market. The entire process of manufacture requires but 24 hr. after the time allowed for hydration of the sand and lime. The only manual handling required in the process is in taking the brick from the press table and stacking them on the cars, this handling requiring the service of only two attendants.



**Layout of Buildings of the South River Sand-Lime Brick Plant.**



**The Brick Press Room of the South River Sand-Lime Brick Plant.**

The South River plant is composed of a group of buildings occupying a ground area of 120 x 220 ft., which are large structures, one and two stories in height. They are of brick and wooden frame construction, except in the sections elevated to contain storage bins and machinery, which are sheathed with galvanized iron. The general arrangement of buildings is shown in the accompanying plan. The sand dryer and storage and also the lime storage are housed in separate buildings at one end of the plant. Of the main building, one side, 73 x 136 ft. in size, is devoted to brick presses and the hardening cylinders, while on the opposite side are located the boiler and engine rooms, the hydration bins and the tube mills and mixers. This arrangement of the various sections is the result of careful study to provide for economical handling of materials from the raw ingredients to the finished product. The sand dryer is located on an outer corner convenient for receiving sand hauled from the bank, while the house in which the lime is stored and ground is located adjacent to the railroad siding for convenience in unloading direct from cars. These materials pass first to the tube mills, for which purpose a belt conveyor is provided between the lime house and the tube mill room, and an elevator next to the sand bin for the handling of the sand. At the delivery ends of the tube mills are the mixers, below which, in a pit, provision is made for delivery of the hydrated product to an elevator by which it is hoisted and dumped into the elevated hydration bins alongside. The hydration bins, each of which holds a supply of material sufficient for a day's operation, have been located directly in line with the six brick presses to permit convenient delivery by a single cross-belt conveyor to the various press feeders. For the handling of the moulded product, it will be noted that the tracks leading into the hardening cylinders are arranged so that one passes in front of each of the brick presses, which permits the products of each press to be handled directly to a hardening cylinder, thus obviating the necessity of complicated storage tracks and loss of valuable space. It is to be further noted that there are narrow-gauge track connections at the opposite ends of the cylinders which are utilized for removing the brick from the cylinders for loading into cars for shipment.

The sand-drying equipment of the plant consists of a rotary fire drier having a capacity of 30 tons of sand per hour, and also a steam coil drier in the elevated bin in which the sand is stored. Sand is handled first to the rotary drier and then, after fire drying, is elevated to the storage bin. The latter contains large hot water coils arranged at the base in the form of a grate, which are effective in maintaining the sand in dry condition during storage. This storage bin has a capacity of 1,200 tons of sand which is an amount sufficient for a three days' run of the plant. The rotary drier is a cylindrical fire drier with a shell 6 ft. in diameter by 50 ft. long, the firing furnace and feeding hopper being at the outer end, while the sorting screen and elevator are adjacent to the sand bin. The sand is raised to the bin by an elevator between the fine receiving hopper of the drier and the bin. The drier and its driving machinery were built by the United States Engineering Co. Sand is at present hauled to the drier by dump cars on a system of standard gauge tracks extending from the plant to the bank; the cars are loaded by a clam-shell dipper operated by a locomotive crane, and are dumped at the drier whence the sand is shoveled into the latter. The locomotive crane is now also used for hauling the cars from the bank; but it is intended later to use a small locomotive especially for this purpose.

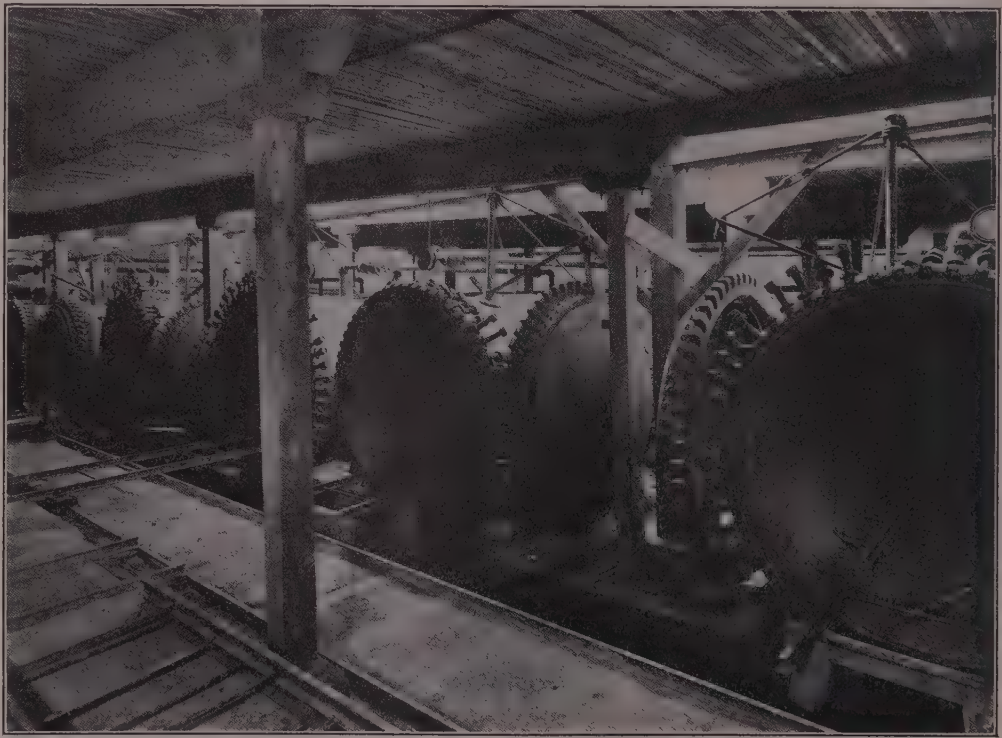
The equipment of the mixing room embraces three tube mills in which the sand and lime in equal quantities are ground into intimate contact prior to the hydration process, and also three pug mill mixers in which the proper proportions of the ingredient are finally secured. The tube mills consist of horizontal cylinders 5 ft. in diameter by 22 ft. in length, which contain each 8 tons of flint pebbles for the grinding process. They are driven at slow speed by compound gearing, which drive is also utilized for the feeding mechanism. The latter consists of a bucket feeder which delivers measured quantities of the lime and sand to the tube mill and additional quantities of plain sand to a belt conveyor by which it is passed by the tube mill to the mixer at the opposite end. The mixers are located beneath the delivery spouts of the tube mills and after the proper mixing and hydration, deliver by a cross belt conveyor to the elevator for hoisting to the hydration bin. These mills were built by the Abbe Engineering Co.

The six brick presses are Boyd special presses, built by the Chisholm, Boyd & White Co., Chicago. They mould four bricks at each operation, and are designed to submit them to a pressure of 350,000 lb. per brick. They are located in a staggered arrangement in the operating building to facilitate the handling of the bricks produced from the press tables to the narrow-gauge cars alongside, while their feeding equipments have been arranged in a gallery overhead. These equipments consist of spiral mixer feeders which receive the hydrated material from a cross belt conveyor and deliver in measured quantities to the presses as required.

For the hardening process, the brick are piled on small narrow-gauge cars and run into the long cylinders for subjection to steam pressure of 125 lb. Each of the six hardening cylinders is 6 ft. 2 in. in diameter by 74 ft. long and built of boiler plate, with heavy dished steel doors, the design being to withstand to 150 lb. pressure. Each cylinder has a line of 28-in. gauge track passing through it on which the narrow-gauge cars are run, each cylinder holding 23 of the cars carrying in all about 20,000 brick. The cars are of steel construction throughout, with platforms 38 in. long by 64 in wide, this shape proving most convenient for loading. They are fitted with ball bearings and are easily operated, each car having a capacity for about 900 brick. They were built by the Ohio Ceramic Engineering Co.; 400 of them have been provided for use at the plant.

All handling of material is accomplished by conveyors or other mechanical means, elevator bucket conveyors being used to deliver the sand to the storage bin and, after mixture, to the hydrating bin. In addition numerous belt conveyors are made use of for the handling of materials both wet and dry. For the loading of cars on the adjoining railway tracks, a 5-ton Industrial Works locomotive crane is used, by means of which the small narrow-gauge cars carrying brick from the hardening cylinders, are hoisted bodily and delivered directly into railway cars on the adjoining railway siding to permit the brick to be unloaded just as they come from the presses without intermediate handling. The locomotive crane is also arranged for self-propulsion and is thus available for the shifting of railway cars upon side tracks at the factory. For loading barges for water shipment, the narrow-gauge cars are loaded from the hardening cylinders on a special transfer car carrying six of the small cars, which is moved by the locomotive crane to the dock for similarly loading on the boat.

The power equipment of the plant consists of four horizontal return-tubular boilers of 150 h.-p. capacity each, and a 500-h.-p. Corliss engine. The boilers operate at 125 lb. pressure and are set in plain brick settings with hand-fired grates. Products of combustion are removed by a 100-ft. stack 60 in. in diameter, which is located outside the boiler room. The engine, which is a Hamilton-Corliss, of the simple non-condensing type, is located in an adjoining room and drives the machinery through a belt connection to a line shaft extended longitudinally in the brick-press room. It has an 18-ft. flywheel, the drive being through a 36-in. three-ply belt.



**The Steam Cylinders for the Hardening Process.**

The plant was designed and equipped by the Standard Brick Machinery Co., 114 Liberty St., New York, who are specialists in brick machinery construction, and are sole owners of the rights and patents for the Huennekes system of brick manufacture. The equipment of conveyors, transmitters and mixers was supplied by the Stephens-Adamson Co., Aurora, Ill.

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Right of Way Through Gore Canyon of the Grand River, in Colorado, has been secured by the Denver, Northwestern & Pacific R. R., after a long legal contest with the national government. It had been proposed to utilize this canyon for an irrigation storage reservoir at some future time, but owing to the value of extensive mining lands that the new railway will develop the irrigation project has been at least temporarily abandoned. The opportunity for the railroad to use the canyon saves a long detour and the location of the line at high altitudes.

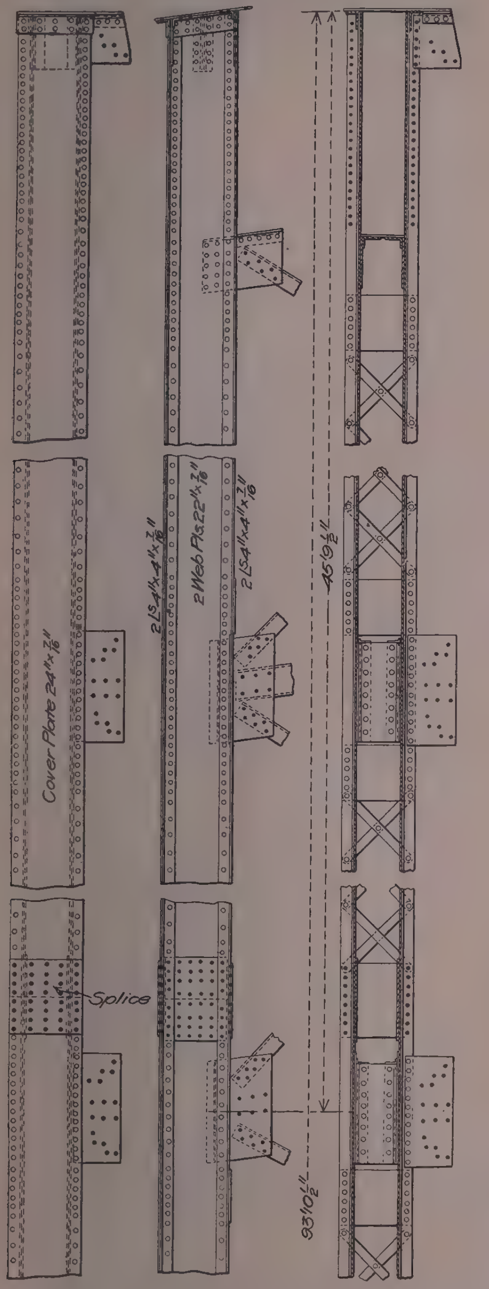
## The Rondout Viaduct on the West Shore Railroad.

The Rondout Viaduct, officially known as Bridge 141 of the West Shore R. R., is a double-track structure 1,228 ft. long and 154½ ft. high from water level to base of rail, which crosses the navigable channel of Rondout Creek near the Hudson River, about one mile south of Kingston, N. Y. It replaces a much lighter superstructure built on the same axis and with approximately the same substructure. The method of erecting the new superstructure so as to displace the old one without interrupting traffic was a very interesting and ingenious one which overcame some of the most difficult conditions encountered in bridge renewals and was described in this journal on April 7, 1906.

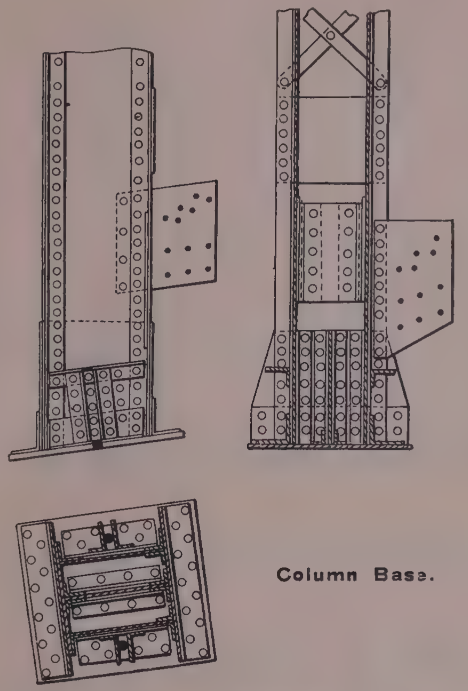
The 3,000-ton new bridge weighs amout 50 per cent. more than the old one and includes two Pratt truss spans with undivided panels. One of them is a deck structure with riveted connections and has a length of 143 ft. The other is a 270-ft. pin-connected through span. Both of them are over the water and are supported by special steel towers. From the shore ends of these spans the bridge is extended across the valley on viaducts having steel towers 29½ ft. long, which support four lines of plate girders arranged at one end as indicated in the accompanying general elevation. At the other end they are uniformly 29½-ft. and 15½-ft. alternating spans, corresponding, except in these dimensions, to those here shown. They are designed for a live load on each track consisting of a train weighing 4,500 lb. per linear foot, preceded by two Cooper's E40 locomotives coupled. High train speeds are provided for and the unit stresses are taken so low that locomotives 20 per cent. heavier than those specified can be safely used. The bridge was designed according to the standard specifications of the New York Central and Hudson River R. R. Co., and is built throughout from mild steel. Rivet holes were drilled from the solid in all compression and tension materials more than ¾ in. and ⅝ in. thick respectively, and were punched and reamed in all other material.

All of the towers except those under the trussed spans are of uniform construction corresponding to the general diagram. Each has two bents 29½ ft. apart on centers and each bent is made with two columns about 19½ ft. apart on centers at the top and battered about 1:8. They are X-braced with pairs of angles latticed together, and have at the panel points of the X-bracing horizontal struts made of pairs of channels latticed and supported at their middle points by riveted verticals from the centers of the panels next above them. The two bents of each tower are braced together longitudinally in a similar manner in panels corresponding with those of the transverse bracing. All of the upper panels of the towers are uniform, the variations due to the different heights and the irregularities of the ground being made entirely in the lower panels. Although the surface of the ground is very uneven, most of the bents have both column duplicates, but in six cases one column is shorter than the other and the strut connecting their feet is inclined from 30 to 45 deg. In that portion of the viaduct not shown by the diagram the columns of the longest tower are made in three sections each; those in the shortest tower are made in single pieces and those of the three remaining towers are made in two pieces. In all of the regular bents the tops of the columns are united by single transverse girders riveted to the inner flanges of the columns and carrying on their top flanges two of the main longitudinal girders, the other two girders being seated directly on the center lines of the column caps.

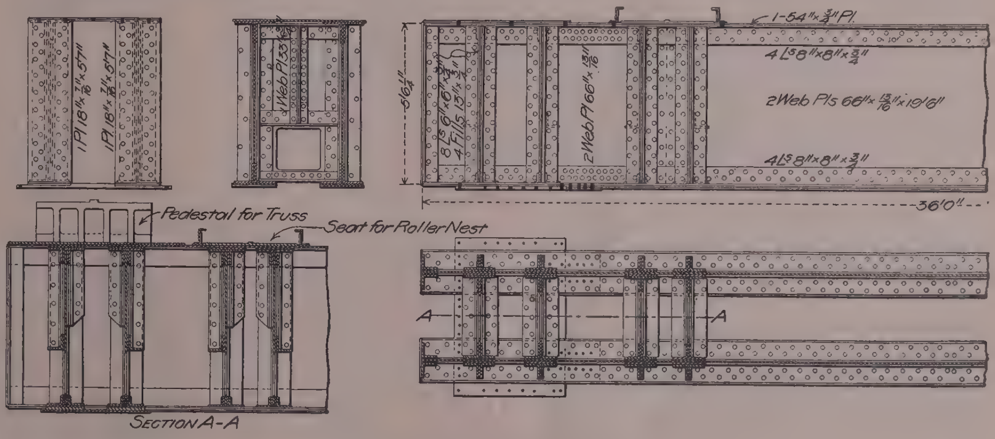
The columns have rectangular cross-sections made with a pair of built channels and cover plates and are latticed on the fourth side. Transverse bracing is field-riveted to pairs of jaw plates shop-riveted to the column webs, the upper ones being connected by a horizontal shelf-plate to form a seat for the transverse girder, and the lower ones being connected by approximately vertical diaphragms inside the column which tie the webs of the latter securely together. Longitudinal bracing is field-riveted to connection plates shop-riveted to the inner faces of the flange angles. Splices are made with double cover plates over the webs and single cover plates over the flanges of the columns, all of the rivets in them being field-driven. At the foot of the column the webs are connected not only by the diaphragm between the jaw plates for the trans-



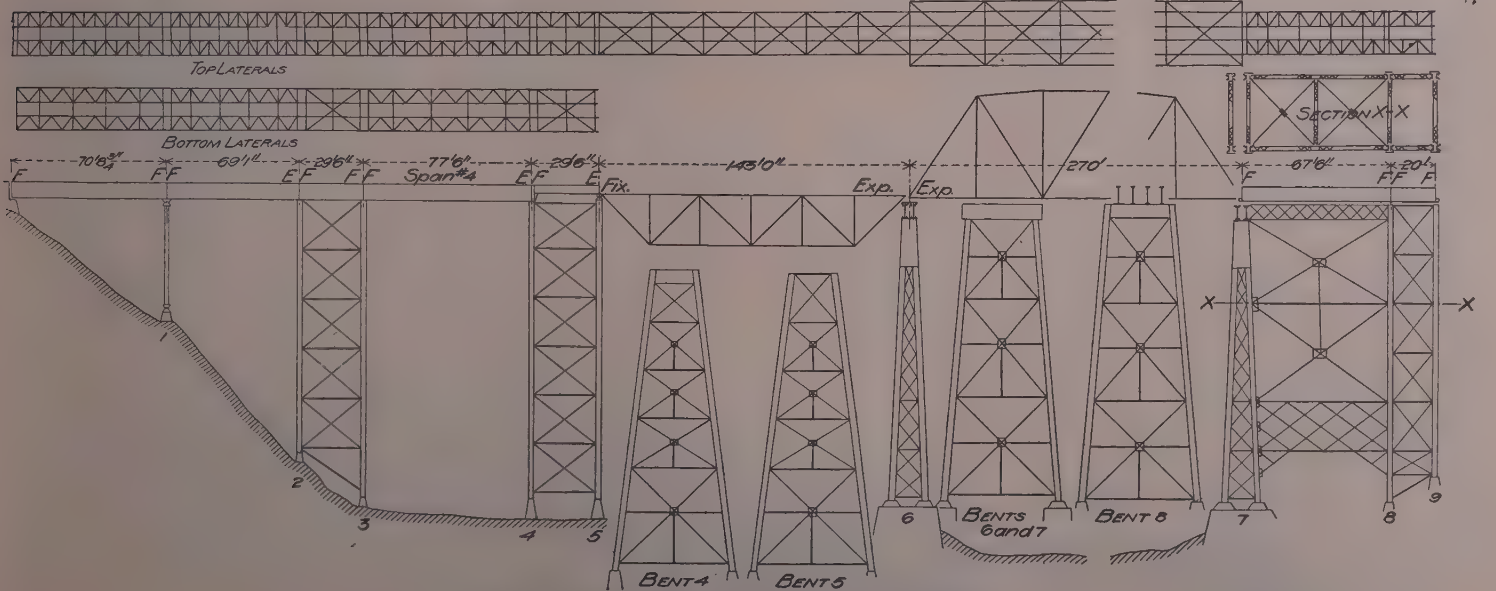
Upper Section of Typical Column.



Column Base.

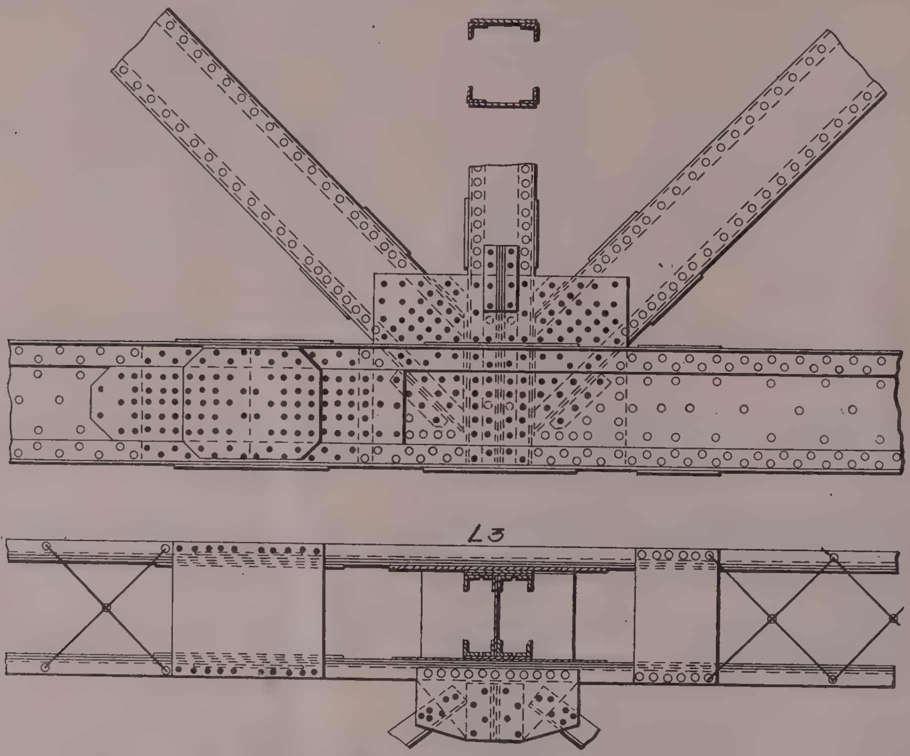


Box Cross Girder, Bent 6.



Part Elevations and Plans of General Diagrams.

verse bracing, but there is an additional diaphragm at right angles to it which is parallel to the column webs and helps distribute the pressure over the base plate. Horizontal angles are riveted across the outer faces of the webs near the feet of the column to afford bearing for the anchor bolts, which pass between pairs of vertical distribution angles with their ends fitted against the angle flange and against the base plate. The ⅝-in. planed base plates are seated on larger bed plates 1¼ in. thick, between which and the masonry there is inserted a ¼-in. sheet of lead of the same dimensions.



Deck Span Bottom Chord Splice and Connections.

The transverse girders connecting the tops of the columns have their ends beveled to correspond with the batter and are provided with ½-in. connection plates, 24 in. wide, riveted to the end angles and projecting beyond their edges so as to afford space for one and two rows of field-driven rivets, 50 and 100 respectively, at each end of the girder. The flanges are made with pairs of 8x8x½-in. angles with single 18x⅜-in. full-length cover plates, and have bearing plates ⅞ in. thick on the top flanges to receive the ends of the intermediate longitudinal girders, the shear at these points being provided for by double pairs of 6x4-in. web-stiffener angles.

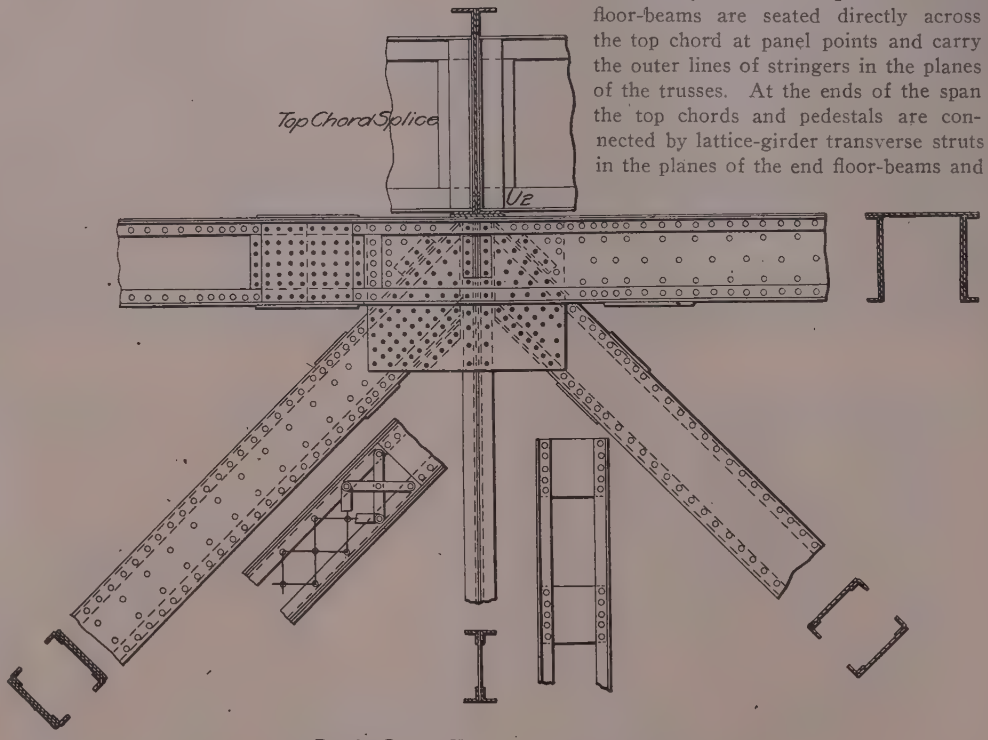
Tower 6 between the two trussed spans is made with two bents similar to the regular bents except that they are inclined toward each other at the top and are braced together longitudinally with short panels of X-bracing, which virtually act like the web of a latticed girder. Each column is made in three field-spliced sections, and the top sections of one column in each bent are shop-riveted together forming a single piece, which is shipped separately and serves for the upper third of the longitudinal bent. Each member is provided with a 15/16-in. cap plate about 5 ft. square, planed on the upper surface to afford seats for the transverse girders. The details of the columns and their connections correspond with those of the regular columns except at the feet, where they have planed base plates seated on cast steel pedestals to which they are secured by sixteen 15/16-in. turned bolts. The pedestals, 2 ft. high, have horizontal top and bottom plates connected by vertical and transverse webs about 6 in. apart in the clear and from 2 to 2½ in. thick. The 50x64-in. base is secured to the masonry by four 1½-in. bolts.

The twin transverse girders seated on the top of tower 6 are fastened together by a single 54x¾-in. cover plate which is riveted to both top flanges and makes them virtually form a single box girder. The webs of the constituent girders are connected by four vertical transverse diaphragms at each end. One pair of these diaphragms is centered over the columns and in the plane of the long span truss. Another pair of diaphragms is spaced 5 ft. 3 in. from them on centers and is symmetrical with the center line of the short-span truss. Both sets of diaphragms stiffen the girders to receive the concentrated loads from the truss pedestals; that for the long span is a fixed end and is seated directly on the girder, that for the short span is an expansion bearing and a roller nest is placed between it and the girder and is secured laterally by pairs of transverse angles riveted together to form Z-bars, which cover the ends of the rollers and are bolted to the top flange of the girder.

Tower 7, at the opposite end of the 270-ft. span is essentially like tower 6, except that it has on one side connections and longitudinal bracing to bent 8.

Bent No. 1 corresponds with the bents in the towers except that it has no longitudinal bracing and the lower ends of its columns are fitted with shoes and pedestals connected by horizontal pins, forming an axis about which it can revolve slightly so as to act as a rocker bent. It is not provided with anchor bolts, but the base plate is secured by turned bolts to a riveted shoe and a similar shoe is bolted to the cap plate. These shoes have three webs each and engage pins locking them to reversed shoes or pedestals. The lower pedestal is seated on the masonry with a ¼-in. lead filler plate, and the upper pedestal has a horizontal base plate bolted directly to the lower flanges of the outside girders. The webs of the shoes and pedestals are in the same planes and have half-hole pin bearings. They are locked together by reinforcement plates riveted to the outer and inner faces of the shoes and pedestal webs alternately, and provided with full pin holes.

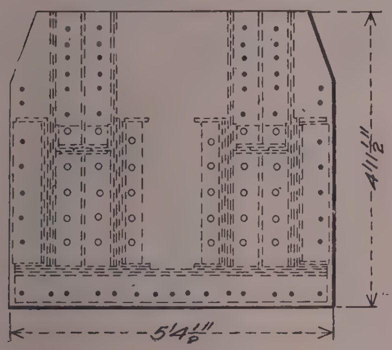
The 143-ft. deck span is made with two riveted trusses 23 ft. 10 in. deep and 19 ft. 6 in. apart on centers. The connections and the cross-sections of the members correspond to the typical details shown. All connections are field-riveted, the top chord being shipped in three sections and the bottom chord in two sections. The connection plates at the ends of the top chords are continued below the lower flanges and are stiffened by vertical angles and a transverse diaphragm to form a sort of shoe receiving the pin bearing in the ordinary double-web pedestal. The floor-beams are seated directly across the top chord at panel points and carry the outer lines of stringers in the planes of the trusses. At the ends of the span the top chords and pedestals are connected by lattice-girder transverse struts in the planes of the end floor-beams and just below them. The shore end floor-beam is provided with deep pockets projecting from the web and furnished with special filler castings fitting their curved bottoms to receive the ends of the longitudinal girders in the adjacent spans.

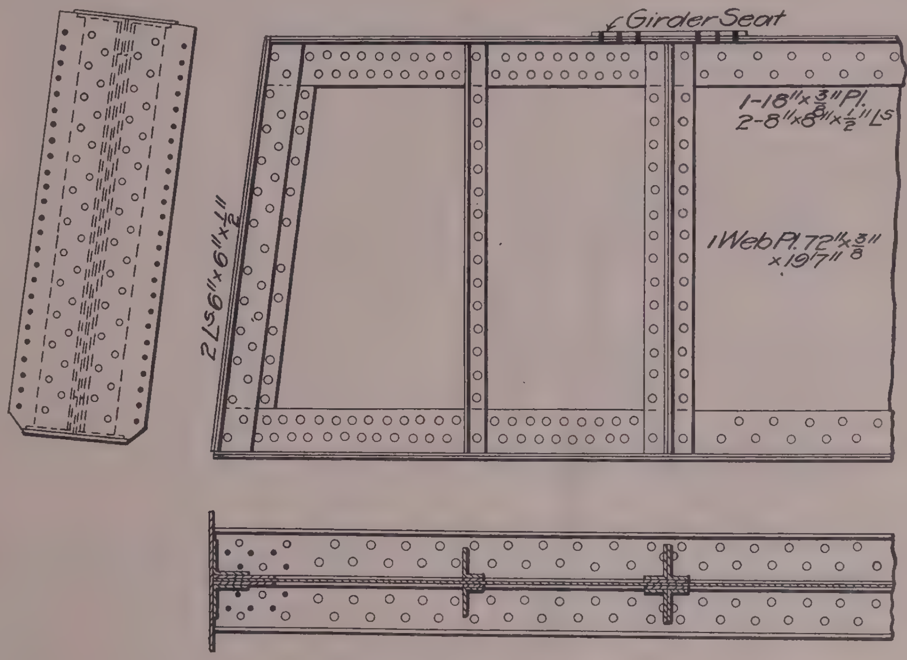


Deck Span Top Chord Details.

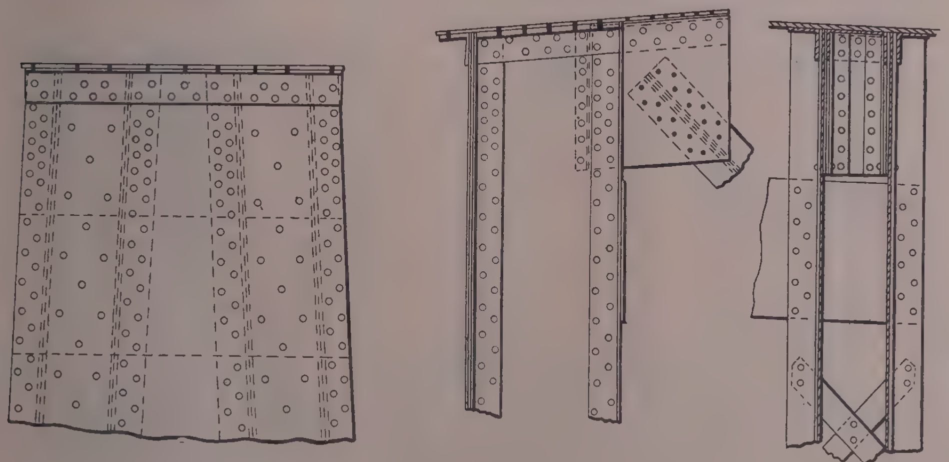
At the east end of the bridge the plate-girder spans are longer than at the west end and the girders have a uniform depth of 90 in., except in the tower span adjacent to the 243-ft. deck-truss span where the depth is reduced to 40 in. so that the river ends of the girders can be supported in the pockets on the end floor-beams as already mentioned. The shore ends of these girders are supported on brackets connected to the end vertical web-stiffeners of the girders in the 77½-ft. span, the latter taking bearing across the full widths of the columns in the tower bent at this point. A similar construction is provided at the shore end of the girder in the tower next beyond the 270-ft. span.

In this span both ends of the girders are fixed and at the river end they abut on the column center against the ends of the 67½-ft. girders and are field-riveted to them through the vertical stiffener angles. At the shore ends they are seated across the full width of the column caps, and instead of having projecting brackets they are made with an extension of the lower portion of the web, shop-spliced to the end panel and riveted to the prolonged bottom-chord angles making the seat for the adjacent 50-ft. 6-in. girder integral with the 20-ft. girder, and giving the latter the appearance of a notched end. Both girders are fixed at this point and are field-riveted together through their end vertical angles. The river ends of the 67½-ft. girders have wide seats across the full width of the double transverse tower girders and are notched like those last described to afford seats nearly over the tower for the stringers of the 270-ft. span.





**Transverse Tower Girder G.**



**Top of Bent 6.**

Between the 20-ft. girder shown on the general diagram and the west abutment there are five spans of 29½-ft. tower girders alternating with six spans of 50½-ft. intermediate girders. All of these are of regular construction, made duplicates for the corresponding spans and having webs 60 in. deep. The ends of the girders abut on the center lines of the tower columns; on alternate tower bents, both girders have fixed bearings and are field-riveted together through their end vertical angles. On the other bents the short girder has a fixed bearing and the long girder has an expansion bearing sliding on the tower caps, to which it is connected by guide strips engaging the edges and upper surfaces of the lower flanges.

All of the girders in the viaduct have web plates ⅜ in. thick, 6x6-in. flange angles, 13x⅜-in. web splice plates and 3½x3½-in. intermediate web-stiffener angles with fillers throughout. All of the flange angles are made in single full-length pieces, and the ends of the girders are milled to exact length and bearing on the end vertical angles. All girders take bearing on sole plates riveted to the lower flanges and these in some cases are extended to form connection plates for the lateral angles. In the 50½-ft. span the flanges are reinforced by one full-length and one part-length 14-in. cover plate, in the 29-ft. 4-in. spans, the top flange is reinforced by a full-length 14x⅜-in. cover plate and the bottom flange by a shorter plate of the same section. In all other girders the flanges are reinforced by one, two or three cover plates as required. In all spans there are zigzag lateral angle braces field-riveted to connection plates on the top and bottom flanges of each pair of girders. In the top system there are transverse struts at alternate panel points and there are vertical sway-brace frames at the ends of the spans. The two girders for one track are braced to those of the other track in the same span by transverse struts at the ends and at one, two, three or four intermediate points according to the length of the span. The maximum weights of the transverse girders are about 34 tons and of the longitudinal girders 20 tons.

The erection of that portion of the viaduct shown in the general drawing was accomplished with the falsework necessarily built for the removal of the truss spans of the old bridge. The remainder of the erection was accomplished without falsework, the new structure being assembled in approximate position, the old viaduct removed and the new adjusted to final position without interrupting the traffic. The tower bents were first assembled clearing the outsides of the old towers and temporarily braced to receive the new plate girder spans which were connected up complete, the tower spans being supported clear of the bents by the overhanging ends of the intermediate spans. The material was all handled by the long booms of powerful derrick cars running on the viaduct, which afterwards sustained the ends of the new spans while the old towers were removed and the bents of the new ones were jacked into the positions they had formerly occupied. In this way difficulties of replacing so high a structure in the original position and still maintaining traffic were successfully overcome.

The work was designed and executed under the direction of the bridge department of the New York Central & Hudson River R. R., Mr. W. J. Wilgus, vice-president, and Mr. Olaf Hoff, then engineer of structures. The work was commenced while Mr. F. L. Chase was engineer of bridges and was completed in July, 1905, under the supervision of his successors, Mr. G. A. Berry and Mr. A. W. Carpenter. The work was built at the Pencoyd plant of the American Bridge Co.

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An Interesting Engineering Undertaking is stated to be contemplated by the War Department in Chesapeake Bay. This bay is the most vulnerable point on the Atlantic Coast, and would probably be the landing place of any invading force, as the distance between Capes Henry and Charles is so great that the channel cannot be completely commanded by guns at both points. It is now proposed, it is reported, to construct an artificial island on which very strong fortifications can be built, as has been done by the Japanese military engineers for the defense of Tokio. Gen. John P. Story, U. S. A., formerly the head of our artillery forces, is now in Japan. The construction of such an island would be a novel undertaking on account of its great extent rather than the principle involved, for small artificial islands have been built at a number of places for lighthouses and other maritime purposes.

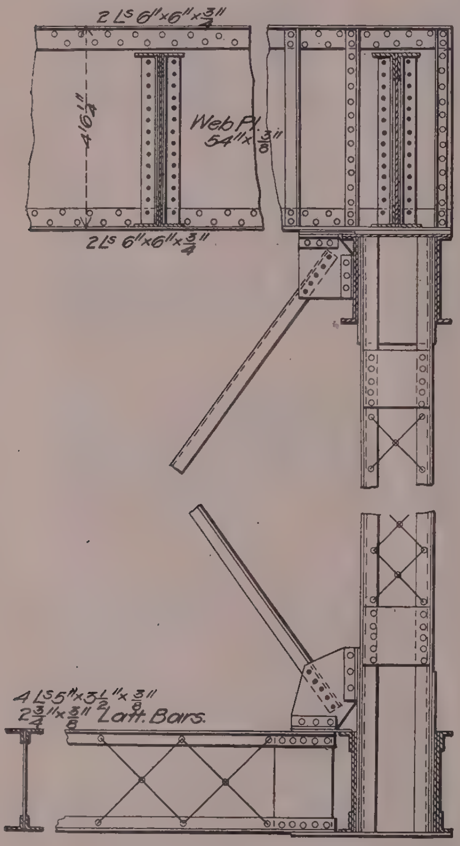
## The Growth of the Pumping Station.

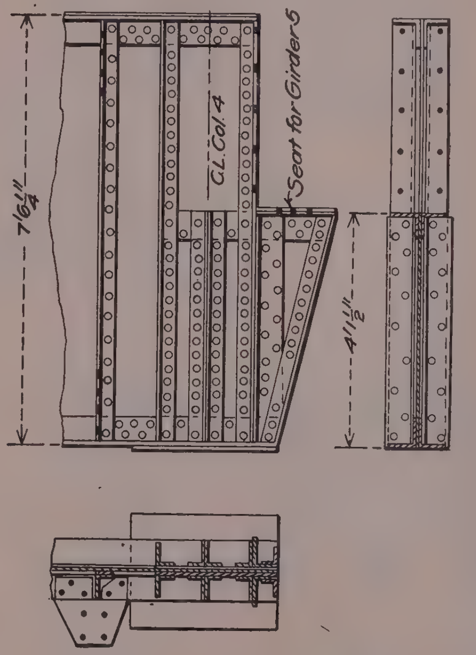
A paper read before the American Water Works Association by Mr. Charles A. Hague.

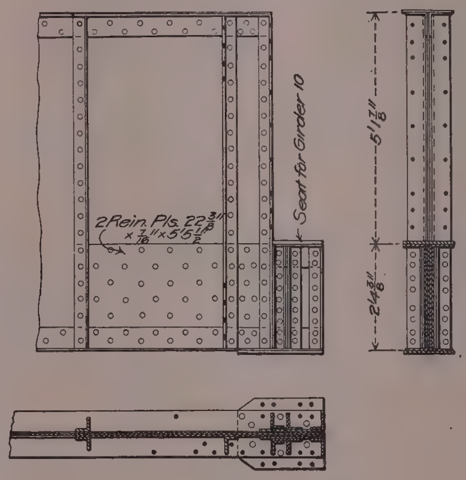
The pumping station herein referred to is the regular water-works pumping station devoted to municipal supply, and specimens of which may be found scattered broadcast over this great land, wherever a community has mustered sufficient courage and progressiveness to establish a system of water works requiring the placing of water under an artificial head or pressure.

The capacities of pumping engines and the dimensions of buildings to contain them, have been on the general increase ever since 1878, a period from which dates the beginning of the wonderful development and rapid building of plant after plant for public supply, to say nothing of the enlargement and improvement of plants already existing in cities large and small.

Thirty years ago pumping engines of 2,000,000 to 5,000,000 gal. daily capacity were considered of quite some importance, and they were to the communities buying and using them. Occasionally a machine of greater capacity than these came into existence, going perhaps as in the case of Chicago and other large western cities as high as 10,000,000 gal.. Chicago early recognizing the fact that she must depend altogether upon pumping; and seeing the shadow cast forward by coming events, even going to the extent of installing pumping engines having a capacity as high as 30,000,000 gal. or thereabouts. But these large machines were exceptional and only occasionally found; the great mass being of very much smaller dimensions, it even being thought in some very important quarters not many years ago that 10,000,000 gal. per 24 hr. would eventually mark the top limit for capacity of the unit in pumping.





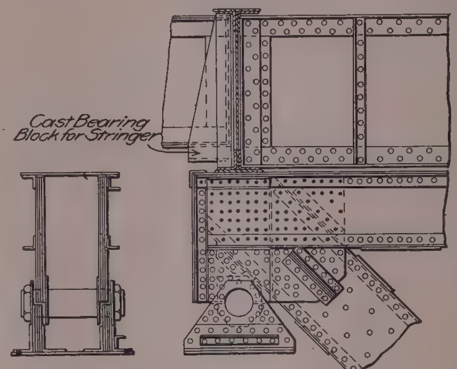


**Half Cross Section of Deck Span; Seat in Span 4 for 30-Ft. Girder, and End of Span 9, Rondout Viaduct.**

But nowadays the 10,000,000-gal. machine is left far behind in the march of improvement, and in the tremendous development of the country, until it has come to pass that 12,000,000 gal. is considered moderate and reasonable; 15,000,000 common; 20,000,000 not unusual; and 25,000,000, 30,000,000, and even 40,000,000 not surprising. For special purposes, like sewage pumping, for example, any one in the vicinity of Boston may investigate a 72,000,000-gal. pumping engine, if desiring to do so. In water works pumping it seems to be a question of unit in proportion to the gross demands, and it will pay any one responsible for the quantity, cost and quality of water for public supply, to carefully consider the relations between the above mentioned items. A good rough rule in a growing plant, occasionally enlarged, is to install each new engine of a capacity equal to the sum of the capacities of the engines already in place, until the new engine reaches the limit of the size of unit appropriate for the plant in question. For example, if a plant has been started with two 5,000,000-gal. engines, when a new one goes in, make it a 10,000,000-gal. engine; or if started with one 5,000,000, and afterwards supplemented with a 10,000,000, after that put in a 15,000,000-gal. engine. The rule must sometimes be modified by taking into account the average and the maximum pumpage, but the general idea is to keep the unit and multiple idea in mind so as to facilitate changing about, and using the reserves to the best advantage. Then by having an eye to the possible enlargement of buildings without entirely destroying the plant, so to speak, much lost time, trouble and money will be saved.

In the growth and development of the pumping station, refinement in machinery, and reduction in cost of manufacture, through better and more appropriate designing, coupled with more efficient and economical shop management, gradually led to higher and higher duties in steam economy, and this gradually changed designs and consequently sizes and forms of buildings. The old fight between low first cost and low duty, and high first cost and high duty, gradually quieted down by the great advocate of low duty and low interest accounts finally being forced to enter the field of a higher economy or retire to the background. He entered it and kept his colors well to the front for many years, but the simplification of the crank and flywheel engine and the increasing complication of the direct acting engine from the very nature of the common aim of both toward high steam expansion, has gradually placed them upon equal footing, so far as cost of construction is concerned, and there are undoubtedly certain limits in the designing of the machinery like close clearance space, for example, in which the absolute control of the stroke by the crank gives that type of engine some slight advantage in every day work. At all events the duty averaged from a fairly good number of engines gives the crank and flywheel machine an advantage which makes it necessary to push the direct acting engine along in the market, where the other one gravitates without material assistance.

The higher steam pressures which go hand in hand with greater and greater steam economy, changed ideas on boilers, brought greater horse power per boiler by enlarging the units and gross demands, and lead to restricting the dimensions of the boiler plant so far as practicable. Probably for regular good every day efficiency the horizontal return tubular is as good as any, and better than most. But where large powers are involved, the room required, and the size of the necessary buildings, place a limit upon the consistent size of boilers and units of this type.



**Deck Span End Panel Point.**

The writer does not look with favor upon underfired boilers with shells of very large diameter, and, although special and comparatively expensive plants, the designing of which has been in thoughtful and dexterous hands, seem to demonstrate the feasibility of using such boilers occasionally, still in the long run and among the many plants built, the boiler for high pressure made up of parts of comparatively small diameters upon the unit principle, seems to economize space, buildings, first cost of complete plant, and other important particulars in that line, to a very satisfactory degree. To bring this detail to a point of issue, if such may prove to be the case, the writer very good naturedly, in the interests of water works owners, but firmly withal, takes the ground that under present circumstances of unit capacity, gross demands, economy of construction, convenience and economy of operation, together with considerations as to buildings and space required; the water tube boiler fitted with automatic stokers, takes the lead as a general steam generator for water works pumping plants.

And to make this complete, it should be supplemented with the further statement that the limits of steam economy in the pumping engine are about reached, both theoretically and practically. Not to go too far back the duty records have been and are, as follows:

| | | | | | |
|---|---|---|---|---|---|
| In the year | 1893, | 154,048,700 | ft. lb. per | 1,000 lb. | steam. |
| | 1895, | 157,843,000 | " | " | " |
| | 1898, | 167,800,000 | " | " | " |
| | 1900, | 168,532,800 | " | " | " |
| | 1900, | 178,497,000 | " | " | " |
| | 1900, | 179,419,600 | " | " | " |
| | 1906, | 181,068,605 | " | " | " |

And finally, the leading work has become crystallized into the vertical, triple-expansion machine, with outside packed plungers, and largely of the crank and flywheel type.

The relation, between the difference in economical duties of pumping engines and the amount of boiler required; may be conveniently illustrated by the accompanying table. The measurable amount of boiler needed being positively indicated by taking 10 sq. ft. of heating surface for each boiler horse power.

TABLE I.

Boiler Horse-Power Required for Each Pump Horse-Power, Counting 10 Sq. Ft. of Heating Surface Per Boiler Horse-Power.

For the Following duties of Engine.

| Duty in ft. lb. per 1,000 lb. of steam. | Boiler horse-power Per Pump Horse-Power. |
|---|---|
| 40,000,000 | 1.63 |
| 50,000,000 | 1.32 |
| 60,000,000 | 1.10 |
| 70,000,000 | .94 |
| 80,000,000 | .83 |
| 90,000,000 | .74 |
| 100,000,000 | .66 |
| 110,000,000 | .60 |
| 115,000,000 | .57 |
| 120,000,000 | .55 |
| 125,000,000 | .52 |
| 130,000,000 | .51 |
| 135,000,000 | .49 |
| 140,000,000 | .47 |
| 145,000,000 | .46 |
| 150,000,000 | .44 |
| 155,000,000 | .43 |
| 160,000,000 | .41 |
| 165,000,000 | .40 |
| 170,000,000 | .39 |
| 175,000,000 | .38 |
| 180,000,000 | .37 |
| 185,000,000 | .36 |
| 190,000,000 | .35 |
| 195,000,000 | .34 |
| 200,000,000 | .33 |

In considering the growth of the water works pumping station, it will be seen that the earlier practice was not free to plan extensively for the future, although it can be seen now that very much better work on this line could have been done than was actually accomplished. The main point is, to look ahead, and calculate as nearly and as clearly as may be, the probable growth of the city and its probable demands in the future for water pumpage. Of course it can not be expected that actual and accurate prophecy need be indulged in; the principal thing is to think of the matter in some shape or other, and have an idea at least in view, that enlargements are bound to come, and increase in capacity is inevitable in the future. It will surprise many to look the pumping stations over throughout the country and observe what a difference in the cost of extensions could have been made for the better, and to what a great extent inconvenience could have been avoided if the original designers of the plant had comprehended to even a slight degree the value of arranging things upon the unit basis, so that additions could be readily and consistently made. Of course thirty years ago, no one foresaw sufficiently to grasp the idea of the rapid strides in development about to come to the country, and therefore could not naturally have conceived the ideas which now seem so natural. It would not have been necessary to provide extensive and costly buildings, intakes, screens, wells, etc., all at once, and then wait for the demands of the community to grow up to the situation. But rather to arrange and design a plant of comparatively moderate dimensions in proportion to the existing demands, so that it might be enlarged afterwards, unit by unit; and it would have been possible and practicable to introduce enough elasticity into the scheme to meet the varying changes in ideas of improvement which it is now seen has taken place. It is rather surprising what a range of new ideas will be opened up to the mind which has been following too closely a rather narrow channel, and it is well known what a difference the point of view makes very often.

The writer has several cases in mind in connection with his own practice which fully illustrates the idea of looking ahead; and showing what a difference in favor of future economy it will make whether the immediate needs are considered alone without thought for the future, or whether by a slight modification the future is considered. One case in particular which will answer to demonstrate the point was as follows:

In a certain city it had been foreseen for some time that the gravity supply which had so far been the entire dependence, was gradually but surely reaching its limits, and that auxiliary pumping must sooner or later be resorted to. The supply from which to pump was available in very good quantity and quality, and at length the move was made, and a pumping station built and connected with the mains for supplying the reservoirs. So far so good. But the fact was not clearly perceived, apparently, from the evidence of what was done at least, that pumping once having been resorted to, its increase was inevitable as time went on, and from the very cause which brought pumping into existence; viz., the increased and increasing demand over and above the gravity system capacity. The first pumping station was built just large enough to contain a 5,000,000-gal. engine with the necessary boilers, and a few years afterwards, about five, it became necessary to enlarge the pumping capacity and a 10,000,000-gal. engine was installed. But to place this second engine it was necessary to rebuild nearly the entire station, but the work was carried out in due season, and then the station just snugly contained the two sets of machinery with an extra boiler. Nine years more passed away, and then another move in the direction of increased capacity became necessary, although no provision or easy method for increasing the station had been considered. The third time of construction a radical difference in ideas was introduced and without undue present cost, a line of increased capacity was forecast which will quadruple the capacity of the station whenever desired, by units of pumpage which may be made to extend 30 or 40 years into the future; and this without materially changing the present building or entailing undue expense beyond the actual cost of added construction when the time comes. The building being planned on the unit principle and the plan made so flexible as to probably cover any possible modification in methods for pumping water in the future. If this look ahead had been made at first, a good deal of money would have been saved, and a good deal of trouble and inconvenience avoided. The first rebuilding would certainly have been avoided completely by a proper attention to possible increase. It is of course not the purpose herein to find fault about the matter, but it is the intention to point a lesson for future thought; the idea being that if something new and useful and economical can be learned now, put the past where it belongs, behind you, and start on a better road, now. The past is a valuable schoolhouse from which a great deal may be learned, but there is no room for regrets in the busy field of water works construction and maintenance.

Make the most and the best of what you now have, and plan more wisely for the future; and in planning for the future do not try to utilize too much of old works about a pumping station, with a mistaken idea of economy. It is often cheaper to put up something entirely new, and when finished connect it to the regular establishment by a short and quickly made change, than to endeavor to rebuild and enlarge already existing buildings and intake accommodations. Sometimes unattractive concessions have to be made to accommodate changes in old structures and appurtenances, which would not be tolerated for a moment with a clear field in view. Do not be extravagant, but also do not be stingy in arranging for the growth of your pumping station.

In the early days of pumping engines it was not realized what the tendencies toward increase amounted to; or to what tremendous sizes the pumping unit would reach. But the view is clearer now, and there is really no good reason with all of the facilities at hand, for straying too far afield in search of the appropriate line to follow. Of course it is difficult to foresee what developments will take place for any very great distance ahead, but with the boiler item brought down so nearly to a scientific basis; with the analysis of coal for determining the amount of fixed carbon, and the possible number of heat units per pound so readily available; with a full knowledge of the heat possibilities demanded by the steam at the working pressure, and the actual capacity of the coal used to furnish the heat; the closely probable efficiency of the boiler to absorb the heat from the burning coal and transmit it to the forming steam; with a very clear perception of the laws of steam expansion and an extremely close knowledge of the slight remaining margin of work to be expected from the steam; with all of these items accounted for and the type of the most efficient engine practically fixed, it is evident that some most radical departure must be made in the science and art of generating and using steam, to defeat a well-devised scheme of pumping station based upon what is so well known at the present time.

TABLE II.

COST OF COMPLETE PUMPING STATIONS.

| Pounds pressure per square inch of the water load worked against. | Cost per million gallons of plant capacity, including a reserve. |
|---|---|
| 30 | $6,750 |
| 40 | 7,000 |
| 50 | 7.250 |
| 60 | 7,500 |
| 70 | 7.750 |
| 80 | 8,000 |
| 90 | 8,250 |
| 100 | 8,500 |
| 110 | 8,750 |
| 120 | 9,000 |
| 130 | 10,000 |

Water works people perhaps do not think enough of the future. Or if they do think of it, or their thoughts are turned in the direction of what to expect, say, ten years ahead, the apparent expense, the necessary study of the subject, and the quantity and quality of the attention necessary to devote to it, makes, sometimes, perhaps often, too much of a mental load when coupled with their regular duties. It will pay, however, to go into the matter to a much greater extent than is commonly done, and an example is given below of how methodically the cost of plants built upon the unit basis may be determined. The table herewith given is sufficiently close for preliminary estimates, but conditions should be looked into carefully for exact estimates. In some actual cases the figures may be too high, and in other cases too low; but they are closely approximate and enough of them are based on records to fairly ensure the table as safe for practical use. In fact, the table is so close that it would be taking chances for a contractor to guarantee the production of results for the figures named, without investigating each case by itself. The work contemplated is for the best type of triple expansion pumping engines and high pressure boilers; a good design and quality of brick buildings, or of stone where stone is cheap; steel trussed and slate-covered roofs; adequate chimneys; properly proportioned and thoroughly screened intakes. The cost given includes everything excepting the land.

There are, of course, cheaper types of pumping engines, but they are necessarily of lower efficiency, and therefore requiring more boiler capacity, more coal storage, and other incidentals which, when balanced up, will tend to keep the figures about the same. A cheaper and less durable sort of building may be used, but in the long run this will need more repairs, which when capitalized will bring the account fully back to the above figures, and most likely exceed them.

It is scarcely possible that the cost of pumping stations for water works will be increased on account of a higher type of engine, because it is pretty evident that the top limit has been just about reached with the new record of a little over 181,000,000 lb. duty per 1,000 lb. of steam. Six years ago it nearly touched the 180,000,000 mark, and might have with some other refinement in the test, at any rate a gain of less than 0.6 of one per cent. in six years, with every nerve strained, is eloquent evidence of the top limit. The Mariott curve is about the nearest approach to perfection in expressing the relation between the work done and the amount of steam used in doing it, apparently possible for the modern steam engine to accomplish; and, if the terminal pressure is taken as expressing the steam used and all of the steam is accounted for by the diagram; somewhere in the immediate neighborhood of 180,000,000 ft. lb. duty with 96 per cent. efficiency of the machine, will be the resulting figure, with a reasonable amount of steam used in the jackets and reheaters charged up against the account. If there were no necessity for the use of jacket steam the figure would approach 200,000,000 ft. lb. duty rather closely, and if superheating can save the jacket steam and vitalize the working steam, the latter figure may in the near future be reached so far as the report on high duty accomplished in a calculation is concerned, but if this pleasing result is obtained by a surface condenser with a consequently smaller air pump, although this type of condenser may require more maintenance account than the jet form, and if the superheated steam is obtained at the cost of coal; if these are so, then, what's the use?

If the steam turbine or the gas engine can step forward at this stage of the performance and the growth of the pumping station, and show something better in the matter of water sent up the hill in proportion to the coal bought and burned, it is now "up to them," to use a slang term which is fast gaining respectability, to do so. And this will of course effect a rather radical change in pumping stations so far as the buildings are concerned at least; probably so far as present evidence goes, however, the changes will be in the line of smaller engine houses and larger boiler and coal houses. Whether the cost of construction of the machinery itself will be materially less than the present record holder, when all difficulties are overcome, and the new era machine is what it must be to stay, time only can tell. The writer is at present carefully investigating the turbine proposition and its possibilities as a practical water works factor, is not yet ready to declare results, but hopes within the next year to be able to state its probable useful and commercial position in the field of pumping water for municipal supply.

Unless something very much out of the line of view at present develops in the near future, the ideal turbine pumping engine will be a turbine steam engine driving a turbine pump, all mounted upon the same frame, as there is a loss in developing power from heat by a reciprocating engine, turning it into the electric mode of motion, and then again changing this into the hydraulic form represented by water under pressure, the latter conversion being through the medium of a turbine pump driven by electricity. No reciprocating steam engine can live under the speed required for turbine pumps under the ordinary water head demanded by the average water works, so that direct connected reciprocating steam end and turbine water end are barred. The direct connected turbine at both ends of the machine has been used on a small scale with doubtful economy, but nothing calculated for the average or large work has been attempted, and of course that is where the greatest benefit lies. When it costs for coal $1,350 per year for each million gallons pumped per day, the total coal bill does not go very far into money for two or three millions of water per day, but when the quantity gets up toward, say, 10,000,000 gal. per day the figures are more important. The larger triple expansion engines both direct acting and crank engines, pump a million gallons of water per day with $625 worth of coal per year for the best records, and $900 is an ordinary good record, while about $1,350 is the steam turbine pumping record so far as the writer can learn, and he is very anxious to know the truth, so as to be in the front rank when the turbine bears the colors. It looks as though the great struggle to keep down the capital account in the turbine outfit must be at least partially abandoned, so far as pumping water is concerned at any rate. If a high rim velocity is what the steam turbine needs, why not increase the diameter and reduce the rate of revolution so as to meet the demands of the turbine pump. The pumping of water is the main thing in a pumping engine, not the accommodation of a new fad in an old idea.

The gas engine as a water works motor is of course entirely undeveloped upon anything like the scale which it will have to reach to be seriously considered in fairly large schemes of water works pumpage. There will be found to be a great variation in the gas production from different kinds of coal, likely as much of a variation as in the generation of steam from different fuels. And this is not only from the difference in the coal itself, but also from differences in gas producing apparatus. But development on this line is going on, and good results in economical and reliable gas production, easy of manipulation, will no doubt be one of the improvements of the future not so very far away, probably claimed to be already accomplished by interested parties. At the Louisiana Exposition, in 1904, there was an exhibition of a gas producing plant sending gas to a gas engine, which in turn was driving a large dynamo, and so a powerful electric current was produced with the burning of coal at one end of the system, with electric lights at the other end, just as we always see it, but with the boiler left out of the combination. This is a little hard on the boiler maker, but then he can make the gas tanks for the future, and at any rate, just at present he need not worry about getting out of a job.

The large gas engines available for pumping for water works have not as yet come prominently to the front, and there are certain adaptabilities necessary to be made touching the matter of speed, for example, which complicates the problem more or less. There are many small pumping plants of course, where the gas engine fits in very well, but there are some incidental items aside from actual fuel economy which have great weight proportionately in a small plant, but which would not be considered in a large pumping plant. The gas engine at its best can probably produce a horse-power with one pound of coal, but this imposes conditions not favorable to the economical pumping of water under pressure suitable for water works stations. The record of 1.02 lb. of coal per indicated horse-power hour is held right here in Boston by a pumping engine especially and completely adapted to the pumping of water upon a large scale. So you will perceive that the modern steam pumping station has already reached the apparent goal of possibilities in low coal consumption, quite as low as the gas engine can accomplish in actual service; the steam pumping station running generally from one pound per indicated horse power on tests, to a range in actual everyday service from 1.33 to 1.98 lb. of coal consumed per indicated horse-power per hour.

But the mere statement of the relation between various rates of efficiency in coal per power unit does not tell so much as a slight analysis of the factors. For example, confining for the moment the comparison to steam pumping engines, the writer has two records, one of 1.02 lb. of coal per indicated horse-power per hour, and the other 1.98 lb. of coal per indicated horse-power per hour, and both records obtained as nearly as could be under similar conditions in actual water works pumping. The fuel calling for 1.98 lb. is slack at $1.50 per ton, and the fuel calling for 1.02 lb. is anthracite coal at $4.50 per ton. The analysis of the coals for heat units on complete combustion was as follows:

Heat units developed by the slack, 11,000 per lb.

Heat units developed by the anthracite coal, 14,000 per lb.

(These are approximate round numbers to make calculation easy.)

In the case of the slack the buyer obtained 146,000 heat units for a cent. In the case of the anthracite coal the buyer obtained 62,000 heat units for a cent.

The plant using the slack consumed 363 heat units per horse-power per minute, while the plant using the anthracite coal consumed 238 heat units per horse-power per minute. The efficiency of the boilers was 70 per cent. in one case, that of the slack, and 80 per cent. in the other, that of the coal; and this reduced to work demonstrated by indicated horse-power gives 13,200,000 ft. lb. for a cent in the case of the coal, and 9,805,680 ft. lb. for a cent in the case of the slack; with the efficiencies of the boilers equalized, and this of course shows that a difference of 3,394,320 ft. lb. for a cent existed in the different economy of the two engines; a comparison between the duties per 1,000 lb. of steam, and the foot pounds for a cent obtained in the two cases, show one to be a little above 30 per cent., and the other a little below 30 per cent. gain, which is near enough for a check.

A comparison between the two methods, one with steam and one with gas, shows that the steam pumping plant, and the gas engine with gas producer are just about on an equal footing, so far as producing an indicated horse-power in proportion to the consumption of coal per hour is concerned; and this of course brings the matter between the steam power plant and the gas power plant down to the question of investment of money in the plant itself, together with the current cost of operation and maintenance. The gas power plant has not made sufficient records yet to enable us to determine very much in the pumping line upon a considerable scale, but whatever it will do in the future, it is perfectly evident at present that the steam pumping station has just about reached its economical limits in the best plants, although as yet only a small percentage of the plants in existence are enjoying the fruits of the advanced practice. The present high type of pumping engine can not be improved apparently to any material extent, so that the very best we can expect is an extremely small increase in economy by means of improved construction.

An increase in coal economy from 6 per cent. to 12 per cent. can most likely be gained by the use of superheated steam, although the interested and intelligent advocates of superheat will probably say that this is too low a figure for the gain. But it must not be forgotten that many of the good records for superheat have been made where engines of only fairly good economy are in use, whereas when the highest type of pumping engines are supplied with superheated steam, the application is then made to steam machinery of the very highest class, where multi-expansion, steam jackets, reheating, etc., are used to reduce the internal losses and condensation to an extremely low point. As already pointed out, very nearly the possible limits have been reached in utilizing the steam in modern pumping engines; the jacket system has been modified somewhat from early practice, and so brought to a high state of efficiency by keeping the heat in the jackets very closely to the balancing point, where the greatest good will be done with the least loss from useless radiation within the cylinder; the distribution of the steam is now very satisfactory and perfect, and the waste room or clearance is brought down to surprisingly low terms by the better arrangements of valve gear and steam ports.

If there is any waste heat in the smoke flues of the boilers, of course re-heaters for the receiver steam can be provided, and this steam made a vehicle for the transportation of the heat now getting away up the chimney, back to the engine, and made to do work there. This is no special credit to any particular type of engine beyond presenting facilities for the use of such heat as the boilers are allowing to escape. But it will reduce the coal bills by turning into useful work some of the heat of combustion unabsorbed by the boiler heating surface. It is not entirely clear why more of this practice of flue reheating has not been done. It certainly has been long enough known. The writer has now before him a supplement of the American Machinist of October, 1878, illustrating the Pawtucket pumping engine designed and built by George H. Corliss, in connection with which flue reheating was very successfully used, the duty given by a small cross compound engine reaching the very satisfactory figures of a little over 133,000,000 ft. lb. with 100 lb. of coal. Within the last five years the Barr Pump Co. used this device at Haverhill, Mass., also in connection with a moderate sized cross compound pumping engine, and the very best of authority reports over 150,000,000 ft. lb. duty per 1,000 lb of steam, which at 9 lb. evaporation, a fairly good figure for boiler work, would amount to 135,000,000 ft. lb. per 100 lb. of coal. The question plainly is, why in the growth of the pumping station has this sensible and easily applied auxiliary not been more utilized?

The quadruple expansion pumping engine with an additional steam cylinder, resulting either in a tandem arrangement for a portion of the engine, or an abandonment of the very desirable three plunger scheme, so favorable for steady hydraulic effects, has no great future before it, and even if it had, there is no good reason for making material changes in the station building, for it will of course be a vertical machine when the present day units are considered, and will likely occupy no more floor space. But likely it will never come at all to any great extent, for, with the 33 to 40 expansions practicable with the triple machinery possessing such admirable mechanical lines, and with the conversion of heat into work about up to the limit, there is in fact no room for the quadruple expansion machine. Some people not specially familiar with the matters pertaining to pumping stations rebel at the idea of even going away from a compound engine, and scout the idea of tripling a machine, but basing their notions strictly on, to themselves, unknown quantities. The distribution of water into a force main from three plungers has never been surpassed and likely as not never equaled, and in addition to that fact, and in the face of a good deal of talk, the triple engine holds the economy record far ahead of compound machinery.

By looking backward over the road traveled during the last twenty years of growth of the pumping station, it will be readily perceived that the demand has always been for a higher and higher class of pumping engine, and as the reduction of the fuel expense became more and more of an object and more and more clearly possible, and there was a better understanding of the whole subject, the engineers and the men who pay the bills were brought closer and closer together, until to-day it is surprising to see what a high type of machine has been produced for a price which in the past would have been considered simply ruinous to the builder. In the old days the competition was between machinery at a low cost, but consuming a considerable quantity of steam and coal; and machinery at a high cost consuming a comparatively small quantity of steam and coal. This, of course, brought the fuel and interest accounts into antagonism, and in many cases the most economical lines, all things considered, were worked out, the consideration of size and cost of buildings not infrequently coming into the controversy. The Worthington pumping engine, in 1878, fairly held the front line in the form of a direct acting, non-rotative, compound condensing machine, and in many cases successfully disputed the field with the many odd and unrepeated forms of the crank and flywheel pumping engine, forging at that time to the front bearing the standard of a higher steam economy. For a good many years the direct acting engine as an all around better proposition held sway, and for durability and reliability as a machine for pumping water for public supply has never been excelled. But gradually the financial end of the crank and flywheel manufacturing establishment and the engineering end drew closer and closer together; then the Worthington engine took on a high duty attachment and the competition went merrily on. The problem was to reduce the capital account by simplifying the design, and keep on raising the duty; at least simplifying the design of the crank and flywheel engine, and a task very effectually done by Edwin Reynolds of the Edward P. Allis Co. In other words the problem was to maximize the efficiency, minimize the cost, and maintain the durability at the high level of the Worthington mark. The two former have been accomplished, but when we see one of the old-time direct-acting pumping engines plodding along after over a quarter of a century of hard work, and apparently in good health and spirits, we are not quite ready for a vote yet on the last of the three counts given above. Still the latest types of the crank and flywheel machine are doing very well, and the commercial points seem to be very well met in many cases, all things considered.

When the possibilities of water works pumping began to attract broader attention, and it began to dawn upon the minds of those interested in the production of such machinery, that the growth of cities, the increased demands for water pumpage regardless of what became of the water, and the increase in the size of the pump units, demanded a higher economical type of machine, many attempts were made to retain the simplicity and low cost of the direct-acting engine and at the same time secure the saving in fuel incidental to a higher steam expansion. But the presence of an obstinate fluid demanding steady propulsion at one end of a machine, and the use of a highly expansive fluid demanding tremendous differences between initial and terminal pressures to secure economy, at the other end of a machine, put designers to their trumps, and a long line of unrepeated failures ending with increased complication in the perfected machine, seems to be the best that can be shown by the record.

So far as the types are concerned, the growth of the pumping station has finally resulted in but three pronounced types of pumping machinery, the construction of which has been repeated enough times to make them really distinctive. These are as follows: The Worthington high duty engine, both vertical and horizontal. The Gaskill-Holly engine, horizontal. The Reynolds vertical three plunger engine.

Some cross-compound engines are built, but they can hardly be called a type, although in the horizontal form make a very good engine. In the vertical form with the cranks at 180 deg. the engine does very well for reservoir work, but is extremely objectionable for anything like direct service, or where the consumers can feel the pulsations certain to be set up where the pumping column is cut off completely, twice at each revolution, and without any blend of delivery of any sort. In the horizontal form the 90 deg. crank engine is unobjectionable, and answers well even where consumers are involved. But the cross compound vertical with 90 deg. cranks, should be shunned by all hands.

On direct service, with a system of closed pipes without storage, the cross compound would not be quite so good as the Gaskill-Holly engine, on account of the variations constantly taking place in the demands and consequently speed and power, and although the reasons for this are perhaps of too technical a nature to be embodied in a general water works paper, belonging rather to papers dealing with engineering strictly, the writer will go far enough to say that any change in power in the cross-compound engine varies the relation between the work done in the high and low pressure cylinders at opposite sides of the engine, and so destroys more or less the economy and regularity of the engine at work under a variable water load, and a load which varies the speed as well as the power, quite contrary to the variations in the work of a mill engine where the speed is practically constant. With the Gaskill-Holly pumping engine each side of the machine is a complete compound engine and whatever variation one feels the other feels as well, but without interfering with the relations between high and low pressure cylinders at opposite sides of the engine; each side taking and using steam and exhausting into the condenser independently of the other side. The crank shaft simply keeps the pumps in proper relation to each other with reference to the water column, and this pumping engine in general design and good construction is probably the best machine ever brought out for direct service and closed circuits of pipes without storage.

The Worthington horizontal, high duty, compound engine works well on direct service, but attempts to regulate it automatically have been little made, in fact, not much needed, as the compensating cylinders receiving their pressure practically direct from the water load, although through the medium of an accumulator, respond very readily to changes of pressure and speed.

The Reynolds vertical three-plunger engine has not been much used on direct service probably for the reason that this engine is generally used in large units, in systems too large to be really classed as of closed circuits, or mostly used in reservoir service. In an extensive system of pipes such as are used in the larger cities, even if there is no reservoir, as in Chicago, to pump into, there is a certain elasticity inherent in so many branches and outlets which furnish a constant relief and demand, quite the equivalent of a free delivery from the force main into a reservoir a long distance away from the machinery.

The growth and drift of the public pumping station seems to be toward larger and larger units, and the vertical triple expansion engine. Not only larger engines, but also toward smaller triple engines and we begin to be accustomed to seeing 6,000,000 and even down to 5,000,000 gal. triple vertical engines in operation. Just what the next ten years will bring out in the further growth of the pumping station can not of course be definitely stated; it looks extremely doubtful for the dominance of the turbine type in that time, if at all, and the gas engine has not yet really made a good start for the front line. Superheated steam and generally higher steam pressure up to about 175 lb. will probably take place, gradually, and that will likely be the last firing line of the reciprocating triple expansion pumping engine. It will hold this line stubbornly, and it will require a great deal more progress than is evident in any direction at present to dislodge it or even shake it materially. Its capital and fuel accounts even with coal at a moderate price make a very satisfactory showing just now, and the maintenance in the presence of good design and construction will not exceed 2 per cent. in good sized or moderate plants where it is reasonably cared for. Therefore it looks fairly safe to plan away for another generation at least, and look out for the future units during the remodelling of old plants or the construction of new ones, and the perfect plant so far as present evidence goes, will involve the following items: Water tube boilers; mechanical stokers; natural draught at least 0.8 of an inch of water; feed water economizers; damper regulators; coal bought on the basis of 14,000 heat units per pound; 175 lb. steam pressure per gauge; moderately superheated steam by independent apparatus; modified steam jacketing and re-heating; smoke flue re-heating; vertical triple expansion pumping engines of long stroke; 200 ft. per minute piston travel maximum; 20 revolutions per minute maximum; coal per indicated horse power hour, 1 lb. for large plants; coal per indicated horse-power hour, 1.75 lb. for small plants; maintenance of engines, 1.5 per cent. for large plants; 3 per cent. for small plants. These and some other items of similar nature are about what a look ahead discerns as the coming events in the planning, construction, and operation of pumping stations for public water supply.

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The Discovery of Anthracite Coal in Canada will mean much to power interests in the Dominion. Extensive deposits have been reported along the Hudson Bay slope in the neighborhood of the Albany River

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## Concrete Column Tests at the Watertown Arsenal, Mass.

A paper read before the American Society for Testing Materials, by Mr. James E. Howard.

Tests on cements, mortars and concretes, which have been in progress during the past six years at the Watertown Arsenal, have reached the subject of columns. Of these, ninety-nine have been tested, others have been made and await being tested, while still others of the series are yet to be made. The tests embrace columns of different mixtures, ranging from neat cement to those of very lean mixtures, both plain and reinforced with longitudinal bars imbedded therein, or by the several current methods of external lateral reinforcement, consisting of hoops and other means, and also by the combined action of hoops and longitudinal bars. Reinforcing material has been received from the Expanded Metal Co., The Hennebique Construction Co., The Trussed Concrete Steel Co., The Cummings Structural Concrete Co. and the Clinton Wire Cloth Co.

In general, the dimensions of the columns are 8 ft. in height and from 10 to 12 in. in diameter. They are made in molds (excepting a number of those having expanded metal cages which were covered with finer mesh lathing) in a vertical position, of wet mixtures, and hardened in the air. They are tested in a horizontal position. For purposes of transportation, adjustment in the testing machine, and to secure even bearing surfaces, they are built upon iron plates and capped with the same. Side rods with turnbuckles are used to put the columns under sufficient initial compression to permit of being handled.

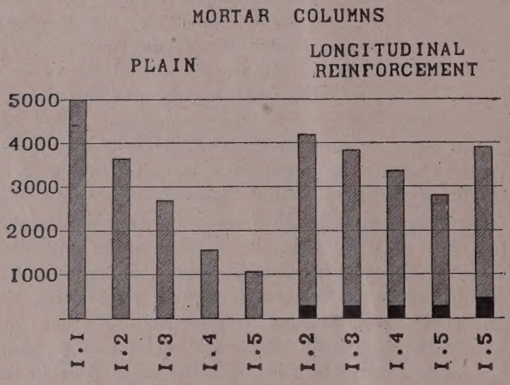

Diagram No. 1.

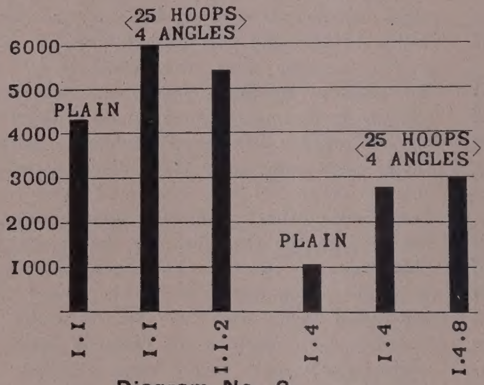

Diagram No. 2.

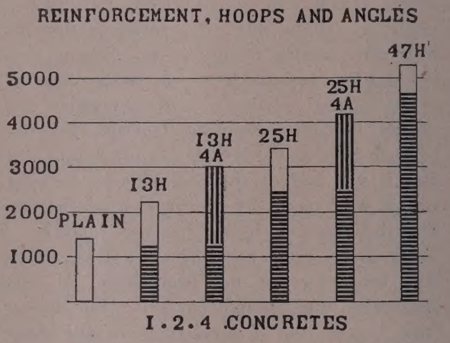

Diagram No. 3.

During testing the columns are loaded with increments of 50 lb. per square inch, measuring the amount of compression under each increment, returning to the initial load and observing the sets. Micrometer observations are thus made on a gauged length of 50 in., equidistant from the ends of the columns. Full details are published in "Tests of Metals," a Congressional document, issued by the Ordnance Department, U. S. Army.

Table I gives the principal features of tests which have been made since the last published report of 1905. These results, in detail, will appear later in "Tests of Metals" for 1906.

In presenting tests reaching up to the time of this meeting, necessarily little opportunity has been available for comparisons and deductions. Indeed, since the series is by no means completed, extended deductions should be held in abeyance. Certain features of interest, however, have been developed and will be referred to, for the illustration of which a number of diagrams have been prepared.

On Diagram No. 1 are represented the compressive strengths of some mortar columns, plain and reinforced with longitudinal bars of ¾-in. twisted steel. The progressive loss in strength of the plain columns, as the mixtures become leaner, will be noted. The ultimate strength of the 1:1 column was not reached; it exceeded the capacity of the testing machine. This mixture was not reinforced. Each of the others was reinforced, four with 8 bars each and one with 13. The percentage of reinforcement was about 2.86 and 4.63, the darker shaded lower ends of the figures representing the relative amounts.

The steel reinforcing bars extended from end to end of the column, and came to a full bearing against the compression platforms of the testing machine. They were used without other lateral support than that which was afforded by the mortar in which they were imbedded. These reinforced columns would be classified as strong columns, according to current practice.

Diagram No. 2 shows the strength of a rich and lean mortar, each of which was reinforced with hoops and longitudinal angle bars; also, corresponding concretes, reinforced. The hoops measured 1.5 by 0.12 in. in cross section, lapped and riveted joints. The plain 1:1 mortar displayed a compressive strength of 4,320 lb. per square inch, which in the hooped column rose to 5,980 lb. The addition of two parts trap rock to this mortar resulted in a strength of 5,433 lb. This loss in strength, by the addition of stone to a mortar, is not peculiar to this example. It has occurred in a number of cases.

The weaker 1:4 mortar was raised by the hooping and angles from 1,050 to 2,766 lb., which in the corresponding concrete reached an ultimate strength of 3,002 lb. The free span between the hoops, 2½ in., permitted this lean mortar to flake off, while the larger pieces of stone in the concrete were retained in place.

On Diagram No. 3, which next follows, the several columns were of the same composition, namely, 1:2:4 mixtures. This diagram is intended to illustrate the effect of hooping alone, and with the further reinforcement of longitudinal angle bars. The compressive strengths of this group are as follows:

| | |
|---|---|
| Plain column | 1,413 lb. per square inch. |
| 13 hoops | 2,232 " " " " |
| 13 hoops and 4 angle bars | 3,029 " " " " |
| 25 hoops | 3,428 " " " " |
| 25 hoops and 4 angle bars | 4,189 " " " " |
| 47 hoops | 5,289 " " " " |

Thus it appears that the hoops and angles each contribute toward increasing the ultimate strength of the columns.

The question of ultimate strength only is now referred to, considering the gain effected by means of lateral reinforcement. It will be shown presently that rigidity of shape does not advance in corresponding degree with the gain in compressive strength. This is regarded as an important feature, not to be overlooked in judging of the advantages of exterior lateral support as compared with longitudinal reinforcement, or the gain in both strength and rigidity which accompanies the use of rich cement mixtures. Any desired strength may be attained by means of lateral reinforcement, if sufficient metal is used; but it is obvious that a certain amount of longitudinal compression of the concrete will be necessary before the lateral reinforcement becomes effective, which, in the case of lean mixtures, involves a large direct compressive movement of the column.

On Diagram No. 4 are represented several columns which are strong by reason of their composition or on account of their reinforcement. In composition, reinforcement and strength, they are described as follows:

| | |
|---|---|
| 1:1 mortar, plain.................above | 5,011 lb. per sq. in. |
| 1:1:2 concrete, plain.................... | 3,900 “ “ “ “ |
| 1:2 mortar, 8¾ in. twisted steel bars... | 4,200 “ “ “ “ |
| 1:5 mortar, 13¾ in. twisted steel bars... | 3,905 “ “ “ “ |
| 1:2:4 concrete, 25 hoops & 4 angle bars.. | 4,189 “ “ “ “ |
| 1:3:6 concrete, 25 hoops & 4 angle bars.. | 3,862 “ “ “ “ |
| 1:4:8 concrete, 25 hoops & 4 angle bars.. | 3,002 “ “ “ “ |

The relative rigidity of these columns, a feature not suggested by a comparison of their compressive strengths, is indicated on Diagram No. 5.

The order in which the compression curves appear is the same as the figures on Diagram No. 4, excepting the 1:1 mortar and the 1:1:2 concrete change places, the latter appearing first on the left of this group. As may be noted, the plain columns display the greatest rigidity of the several types here represented. This has been a noticeable feature in the tests as a whole.

It is even found that plain columns are a little more rigid, over the range of stresses here plotted, than the same mixtures in which longitudinal bars are used as the means of reinforcement. In so many cases has this occurred that some explanation should be sought why the presence of the steel bars, themselves so much more rigid than the concrete, should not result in increased rigidity of the column as a whole. It is not improbable that the settlement in height of the column is so far restricted by the steel bars that minute fissures are developed during the early stages of hardening of the concrete. Internal strains, without the presence of fissures, would hardly account for this behavior. The difference between the plain and the longitudinally reinforced columns is not great, however, in this respect.

The hooped columns are a distinct group, and decidedly more compressible than the others. Comparisons are now being made between columns of different mixtures, and, it may be added, the leanest mixtures are expected to display the greatest compressibility. However, lateral reinforcement, while effective in raising the ultimate strength for loads once applied, does not result in imparting rigidity to a weak concrete. The value of lateral reinforcement, as a method of raising the limit of endurance against long continued or repeated stresses, is a query suggested by an inspection of these curves.

Diagram No. 6 is introduced merely to show the range in compressibility which is experienced, and the sets developed, in different mixtures. The several curves refer to hooped columns, excepting the 1:1 mortar. They are plotted because of their greater strength over the plain mixtures, but the curves are similar in their characteristics.

The moduli of elasticity at successive stages, referring to values over a range of 500 lb. per square inch next above the initial load, are shown on Diagram No. 7. In obtaining these values the columns were loaded with successive higher stresses and then returned to the range from 100 to 600 lb., at which time the micrometer observations were made. The numerical values were as follows:

1:1 MORTAR, PLAIN

| | | |
|---|---|---|
| Original value of E...... | 3,378,000 | lb. per square inch. |
| After a load of 1,000 lb..... | 3,247,000 | “ “ “ “ |
| “ “ “ “ 1,500 “..... | 3,247,000 | “ “ “ “ |
| “ “ “ “ 2,000 “..... | 3,205,000 | “ “ “ “ |
| “ “ “ “ 2,500 “..... | 3,165,000 | “ “ “ “ |
| “ “ “ “ 3,000 “..... | 3,086,000 | “ “ “ “ |
| “ “ “ “ 3,500 “..... | 3,086,000 | “ “ “ “ |

1:2:4 CONCRETE, 25 HOOPS.

| | | |
|---|---|---|
| Original value of E....... | 2,874,000 | lb. per square inch. |
| After a load of 1,000 lb..... | 2,551,000 | “ “ “ “ |
| “ “ “ “ 1,500 “..... | 2,016,000 | “ “ “ “ |
| “ “ “ “ 2,000 “..... | 1,532,000 | “ “ “ “ |
| “ “ “ “ 2,500 “..... | 1,337,000 | “ “ “ “ |
| “ “ “ “ 2,800 “..... | 1,244,000 | “ “ “ “ |

1:3:6 CONCRETE, 48 LIGHT HOOPS, 4 ANGLE BARS.

| | | |
|---|---|---|
| Original value of E....... | 1,220,000 | lb. per square inch. |
| After a load of 1,000 lb..... | 899,000 | “ “ “ “ |
| “ “ “ “ 1,500 “..... | 801,000 | “ “ “ “ |
| “ “ “ “ 2,000 “..... | 912,000 | “ “ “ “ |

1:3:6 CONCRETE, CINDER, 25 HOOPS.

| | | |
|---|---|---|
| Original value of E......... | 702,000 | lb. per square inch. |
| After a load of 850 lb..... | 538,000 | “ “ “ “ |
| “ “ “ “ 1,000 “....... | 426,000 | “ “ “ “ |

Neat cement and rich mortars do not show any considerable loss in the value of the modulus of elasticity when examined over an early range of loads succeeding the application of successively higher stresses.

Other mixtures are subject to decided changes. After the application of each higher load there results a difference in the rate of compressibility under lower stresses, the modulus in some instances dropping to less than one-half its original value. It will be understood from this that the proportion of load carried by steel in combination with concrete is subject to great fluctuations. This feature will deserve consideration in the case of reinforced beams, when they are studied in the manner in which the present column tests are being carried out.

It may be remarked in passing that compressive stresses exceeding 50,000 lb. per square inch are of frequent occurrence in columns tested to

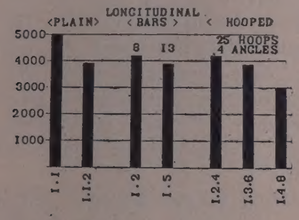

**Diagram No. 4.**

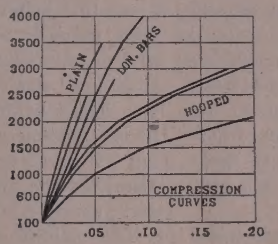

**Diagram No. 5.**

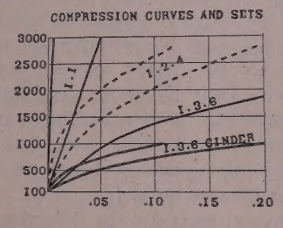

**Diagram No. 6.**

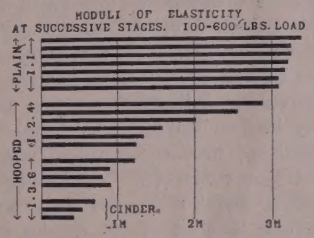

**Diagram No. 7.**

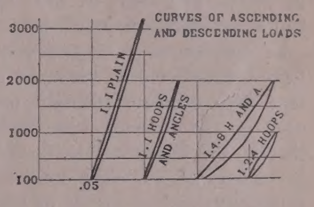

**Diagram No. 8.**

TABLE I.

CONCRETE AND MORTAR COLUMN TESTS AT WATERTOWN ARSENAL, MADE SUBSEQUENT TO LAST PUBLISHED RESULTS, IN TESTS OF METALS, 1905. COLUMNS 8 FT. HIGH.

| No. of test. | Diameter of column. inch. | Composition: Cement. | Composition: Sand | Composition: Stone or cinder. | Composition: Kind of stone or cinder. | Age. Mos. | Age. Days. | Reinforcing metal. | Gross sectional area. sq. in. | Weight of concrete or mortar per cubic foot. lb. | Compressive strength. Total lb. | Compressive strength. Per sq. in. lb. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1718 | 12.35 | 1 | 2 | 4 | ¾ to 1½-in. trap rock. | 5 | 8 | 2-in. mesh wire cage. | 119.79 | 149.6 | 263,538 | 2,200 |
| 1722 | 12.25 | 1 | 2 | 4 | “ “ “ “ “ | 5 | 13 | 3-in. mesh wire cage. | 117.86 | 151.3 | 242,000 | 2,053 |
| 1724 | 12.45 | 1 | 2 | 4 | “ “ “ “ “ | 5 | 13 | “ “ “ “ | 121.74 | 149.4 | 318,000 | 2,610 |
| 1720 | 12.25 | 1 | 3 | 6 | “ “ “ “ “ | 5 | 8 | 2-in. mesh wire cage. | 117.86 | 150.1 | 159,111 | 1,350 |
| 1719 | 12.45 | 1 | 3 | 6 | “ “ “ “ “ | 5 | 8 | “ “ “ “ | 121.74 | 145.7 | 168,000 | 1,380 |
| 1721 | 12.40 | 1 | 3 | 6 | “ “ “ “ “ | 5 | 8 | “ “ “ “ | 120.76 | 143.1 | 183,500 | 1,520 |
| 1723 | 12.34 | 1 | 3 | 6 | “ “ “ “ “ | 5 | 12 | 3-in. mesh wire cage. | 119.60 | 147.6 | 197,340 | 1,650 |
| 1725 | 12.35 | 1 | 3 | 6 | “ “ “ “ “ | 5 | 11 | “ “ “ “ | 119.79 | 149.6 | 206,000 | 1,720 |
| 1734 | 10.40 | 1 | 1 | 0 | None. | 6 | 11 | None. | 84.95 | 132.6 | 367,000 | 4,320 |
| 1735 | 10.40 | 1 | 1 | 0 | “ | 6 | 12 | 25 1.5-in. hoops & 4 angles. | 84.95 | 132.6 | 508,000 | 5,980 |
| 1730 | 10.45 | 1 | 1 | 2 | ¾ to 1½-in. trap rock. | 5 | 0 | “ “ “ “ “ “ | 85.77 | 149.1 | 466,000 | 5,433 |
| 1736 | 10.38 | 1 | 4 | 0 | None. | 6 | 8 | None. | 84.62 | 118.7 | 88,851 | 1,050 |
| 1737 | 10.40 | 1 | 4 | 0 | “ | 6 | 8 | 25 1.5-in. hoops & 4 angles. | 84.95 | 119.9 | 235,000 | 2,766 |
| 1733 | 10.40 | 1 | 4 | 8 | ¾ to 1½-in. trap rock. | 6 | 11 | “ “ “ “ “ “ | 84.95 | 146.6 | 255,000 | 3,002 |
| 1731 | 10.40 | 1 | 2 | 4 | “ “ “ “ “ | 5 | 16 | None. | 84.95 | 150.0 | 120,000 | 1,413 |
| 1740 | 10.38 | 1 | 2 | 4 | “ “ “ “ “ | 6 | 6 | 13 1.5-in. hoops. | 84.62 | 149.2 | 188,900 | 2,232 |
| 1741 | 10.38 | 1 | 2 | 4 | “ “ “ “ “ | 6 | 5 | 25 1.5-in. hoops. | 84.62 | 148.6 | 290,100 | 3,428 |
| 1739 | 10.35 | 1 | 2 | 4 | “ “ “ “ “ | 6 | 6 | 47 1.5-in. hoops. | 84.13 | 149.4 | 445,000 | 5,289 |
| 1738 | 10.38 | 1 | 2 | 4 | “ “ “ “ “ | 6 | 7 | 13 1.5-in. hoops & 4 angles. | 84.62 | 150.7 | 256.300 | 3,029 |
| 1692 | 10.40 | 1 | 2 | 4 | “ “ “ “ “ | 0 | 15 | 25 1.5-in. hoops & 4 angles. | 84.95 | 144.2 | 260,400 | 3,065 |
| 1726 | 10.30 | 1 | 2 | 4 | “ “ “ “ “ | 5 | 12 | “ “ “ “ “ “ | 83.32 | 150.7 | 349,000 | 4,189 |
| 1728 | 12.00* | 1 | 2 | 4 | “ “ “ “ “ | 5 | 12 | “ “ “ “ “ “ | 113.10 | 149.4 | 370,000 | 3,271 |
| 1746 | 10.36 | 1 | 2 | 4 | ¼ to ¾-in. trap rock. | 5 | 12 | 48 1-in. hoops & 4 angles. | 84.30 | 147.2 | 324,000 | 3,843 |
| 1744 | 11.95* | 1 | 2 | 4 | “ “ “ “ “ | 6 | 0 | “ “ “ “ “ “ | 112.16 | 148.2 | 335,200 | 2,989 |
| 1732 | 10.38 | 1 | 3 | 6 | ¾ to 1½-in. trap rock. | 5 | 11 | None. | 84.62 | 148.2 | 63.465 | 750 |
| **1742 | 10.38 | 1 | 3 | 6 | “ “ “ “ “ | 6 | 4 | 25 1.5-in. hoops. | 84.62 | 145.9 | 162,300 | 1,918 |
| 1743 | 10.38 | 1 | 3 | 6 | Cinders. | 6 | 4 | “ “ “ | 84.62 | 101.3 | 96,000 | 1,134 |
| 1727 | 10.35 | 1 | 3 | 6 | ¾ to 1½-in. trap rock. | 5 | 11 | 25 1.5-in. hoops & 4 angles. | 84.13 | 148.3 | 325,000 | 3,863 |
| 1729 | 12.02* | 1 | 3 | 6 | “ “ “ “ “ | 5 | 3 | “ “ “ “ “ “ | 113.47 | 144.6 | 299,000 | 2,634 |
| 1747 | 10.36 | 1 | 3 | 6 | ¼ to ¾-in. trap rock. | 5 | 11 | 48 1-in. hoops & 4 angles. | 84.30 | 138.9 | 212,000 | 2,515 |
| 1745 | 11.95* | 1 | 3 | 6 | “ “ “ “ “ | 5 | 13 | “ “ “ “ “ “ | 112.16 | 142.2 | 259,000 | 2,309 |
| 1714 | 12.00 | 1 | 2 | 4 | ¾-in. trap rock. | 5 | 11 | 3 Kahn bars & 11 hoops. | 113.10 | 145.4 | 265,500 | 2,350 |
| 1717 | 12.00 | 1 | 2 | 4 | “ “ “ | 5 | 8 | “ “ “ “ “ “ | 113.10 | 145.6 | 237,510 | 2,100 |
| 1712 | 12.45x12.47 | 1 | 2 | 4 | “ “ “ | 5 | 11 | 4 Kahn bars & 11 hoops. | 155.25 | 143.4 | 279,450 | 1,800 |
| 1713 | 12.45x12.47 | 1 | 2 | 4 | “ “ “ | 5 | 11 | “ “ “ “ “ “ | 155.25 | 144.6 | 394,000 | 2,538 |
| 1716 | 12.48x12.49 | 1 | 2 | 4 | “ “ “ | 5 | 10 | “ “ “ “ “ “ | 155.88 | 143.8 | 296,172 | 1,900 |
| 1715 | 12.45x12.49 | 1 | 2 | 4 | “ “ “ | 5 | 10 | 4 Truscon bars & 11 hoops. | 155.50 | 145.8 | 367,500 | 2,363 |
| 1705 | 12.02 | 1 | 3 | 6 | ¾ to 1½-in. trap rock. | 5 | 5 | None. | 113.47 | 146.1 | 164,100 | 1,446 |
| 1706 | 12.02 | 1 | 3 | 6 | ¾ to 1½-in pebbles. | 5 | 3 | “ | 113.47 | 128.0 | 143,000 | 1,260 |
| 1707 | 12.00 | 1 | 3 | 6 | Cinders. | 5 | 0 | “ | 113.10 | 101.4 | 78,900 | 698 |

* Exterior shell.

** Defective column; one hoop displaced during construction.

their ultimate resistance, whence it follows that steel employed for longitudinal reinforcement should have an elastic limit not less than the above.

In addition to the changes in the modulus above referred to, the curves of ascending and descending stresses do not coincide, the departure increasing with the application of successively higher loads. This behavior is indicated upon Diagram No. 8, which shows the stress-strain curves of four columns.

These curves were obtained after the columns had been loaded as follows:

| | |
|---|---|
| 1:1 mortar, plain after having been loaded with........... | 3,500 lb. per square inch. |
| 1:1 mortar, 25 hoops & 4 angle bars, after having been loaded with ................ | 5,700 " " " " |
| 1:4:8 concrete, 25 hoops & 4 angle bars, after having been loaded with ................ | 2,500 " " " " |
| 1:2:4 concrete, 25 hoops, after having been loaded with.... | 3,200 " " " " |

Concerning the amount of lateral expansion which accompanies the direct compression of the material, observations have been made on several columns. Measurements have also been made upon the expansion of the hoops of hooped columns during testing. Adjacent hoops have been found working under very different strains. The location of final rupture in columns not reinforced is often indicated prior to reaching the maximum load, by reason of the greater lateral expansion in that vicinity.

Columns have been made for test by long continued loads, and are now sustaining stresses of different amounts. The loads are maintained by means of groups of steel bolts which tighten end plates, between which the columns are located.

In conclusion, it is believed that the present tests are sufficiently advanced to clearly indicate that high ultimate strength may be reached by each of the three current methods of practice; that is, by the use of rich mortars or concretes, by means of sufficient longitudinal metal reinforcement, and by means of adequate hooping or other external lateral support. Rigidity of the columns will be attained by the use of rich cement mixtures or by means of longitudinal steel bars. The rigidity of the mortar or concrete itself is effected practically only by the use of rich cement mixtures. Economy of cost, to attain compressive strength, within certain limits, will be promoted generally by the plentiful use of cement.

## Foreshore Pollution.

An important case, bearing on the question of foreshore pollution, has recently been decided in the Law Courts of England. Prof. Henry Robinson, of Kings College, has furnished the following notes on the case, which deserves notice owing to the decision rendered. The plaintiff, Mr. Foster, being the owner of oyster beds at Emsworth, a village at the head of a tidal creek known as Chichester Harbor, and the defendant, the Warblington Urban District Council, the authority whose outfall sewer discharged sewage on the foreshore of the creek near the oyster beds. It was alleged that the oyster became contaminated by the sewage, and in November, 1902, several fatal cases of typhoid fever resulted from oysters from these beds being supplied for a public banquet at Winchester. The publicity occasioned thereby led to these beds being condemned, and the plaintiff's business ruined. The action was to recover damages for this loss. The case was tried in 1904 before Mr. Justice Walton, and occupied several days.

The plaintiff purchased his oyster beds in 1870, and in 1874 the defendant council carried out some drainage works with an outfall sewer, discharging the sewage near the oyster beds; but a penstock enabled the discharge to be controlled so as to take place at low water on the ebb tide, whereby the sewage would be carried away seaward. In 1895 the Council extended their drainage system, thus increasing the amount of sewage brought to the outfall, and the whole passed away when the tide served, as the use of the penstock had been discontinued. In 1896 Dr. Bulstrode, of the Local Government Board, visited Emsworth, as he was then engaged, owing to the "scares" at the time, in examining places where oysters were cultivated, and he pointed out the danger of the Emsworth beds being contaminated.

When the case was tried the question of title was first raised, and evidence was called to establish this. Then followed a number of witnesses who dealt with the history of the district, and the condition of the foreshore in past years. The fact that the plaintiff had been a member of the Council during the time that the extensions and alterations to the drainage system and the outfall were carried out, made him a party to what he now complained of, and emphasis was laid on this.

The following interesting technical and scientific evidence was then given. Prof. Kenwood stated that he had visited the district and seen the sewage flowing from the outfall sewer over the foreshore and obviously passing over the oyster beds. He agreed with Dr. Bulstrode that the conditions for storing oysters at this place was disgusting. Prof. Robinson followed and explained various float observations that he had made at different states of the tide which proved that the sewage from the outfall must inevitably be carried over the oyster beds at flood tides, and thus cause their pollution. He pointed out that the increased volume of sewage which passed into the outfall sewer since it was made would prevent the penstock being of any use, as the sewer became gorged.

At this stage counsel for the defendants stated that it would now be no longer contended that the sewage from the outfall did not pass over the beds. Dr. Bulstrode then explained the results of his visit to the oyster beds in 1894, when he condemned them, and what happened at the Winchester banquet in 1902 proved that his view was correct, and he stated this in a report he made in May, 1903, after this banquet. Dr. Klein explained the results of analyses he had made of oysters and water from Emsworth in December, 1902. Every sample gave evidence of the conspicuous presence of organisms generally found in sewage. Some contained organisms which were generally associated with gastroenteritis. Dr. Fraser described how 30 cases of typhoid which he had investigated at Portsmouth, had been occasioned by the consumption of Emsworth oysters, and he, as medical officer of health, issued a warning against eating them.

For the defense, it was contended that the Warblington Council succeeded to a bad system of drainage which existed before its members came into power, and if, by reason of the inhabitants exercising their rights to connect with the sewerage system, an increased volume was created, this would give the plaintiff no right of action against the Council, as the plaintiff's beds were exposed to the operation of a sewer which existed before the Council was formed. If he had ground of complaint, he should have moved the Local Government Board, as prescribed by the Public Health Act, 1875, Section 299. It was also argued that any one had a right to drain into the sea, and further, that as the plaintiff had not taken steps for years to guard against the danger, he was guilty of "latches," and could not recover. During the arguments for the defense, the judge observed that, although a prescriptive right to drain on the foreshore existed, and, although the inhabitants had a right to connect their drains with the public sewers, there was no right to commit a public nuisance.

On Jan. 13, 1905, Mr. Justice Walton delivered judgment in favor of the plaintiff. He held that the oyster beds were well defined, and were situated on the soil of the foreshore which belonged to the lord of the manor. The beds had been in the occupation of the plaintiff for a sufficient length of time for him to have acquired a prescriptive title when the acts complained of occurred. It had been contended that the Council had a prescriptive right to discharge the sewage on the foreshore, but he considered that the original use of the outfall sewer did not involve the damage complained of, which arose from the modern practice of connecting drains with sewers. This had largely increased the amount of sewage discharged, and the abandonment of the penstock caused the sewage to pollute the foreshore, instead of being carried out to sea.

He had come to the conclusion that the lord of the manor had not only the ownership of the soil of the fishery, but also the right of "several fishery" as a right belonging to him as owner of the soil. From this, it followed that, by acquiring rights in the soil of the foreshore, the plaintiff had acquired the right of several fishery, and the oyster beds were private beds, the rights to which had been disturbed by the defendants depositing sewage matter in them, which they had no prescriptive right to do, neither could such right be acquired, as it was a public nuisance to a public fishery. The Sea Fisheries Act, 1868, specially Sections 51 and 53, made it criminal to contaminate oysters in private beds. This judgment was appealed against, and the case was heard before Lords Justices Vaughan Williams, Stirling and Fletcher Moulton, the hearing lasting several days. The court unanimously dismissed the appeal, and upheld the decision of Mr. Justice Walton.

The plaintiff claimed £18,000 damages, but it had been agreed at the outset to defer dealing with the amount of damages until the legal matters had been disposed of, and the defendants had been found to be liable. The claim for damages was afterwards dealt with by Mr. Justice Walton, who tried the case in 1904, and in May, 1906, he gave his judgment to the effect that the plaintiff, Mr. Foster, has been deprived of the use of the oyster beds at Emsworth from December, 1902, to the present time. He had also suffered some damage in consequence of the removal of his oysters from Emsworth to Hayling, as well as from mortality among the oysters. There was also some disturbance to his business in consequence of its removal from Emsworth to Hayling. He was entitled to some damage under all the above heads. But the plaintiff made a much more serious claim. He said that, in 1902, the public became alarmed in connection with the contamination of the Emsworth beds, and that he suffered a loss of business, for which he claimed some £10,000.

He did not think the plaintiff could recover for general depression of the oyster trade. It was not strictly caused by any act of the defendants. In 1902, the plaintiff was selling the oysters with the knowledge that they might be contaminated with sewage. The plaintiff must bear the loss caused by the general depression of the market, in the same way as other people had to do. But for the particular loss arising to the plaintiff under the heads already mentioned, he awarded him the sum of £850, the plaintiff to have the costs of the former hearing, but each party to pay their own costs of the present hearing.

While the decision rendered in this case is interesting there are probably only few instances in the United States where conditions exist that even approach those which occasioned this suit.